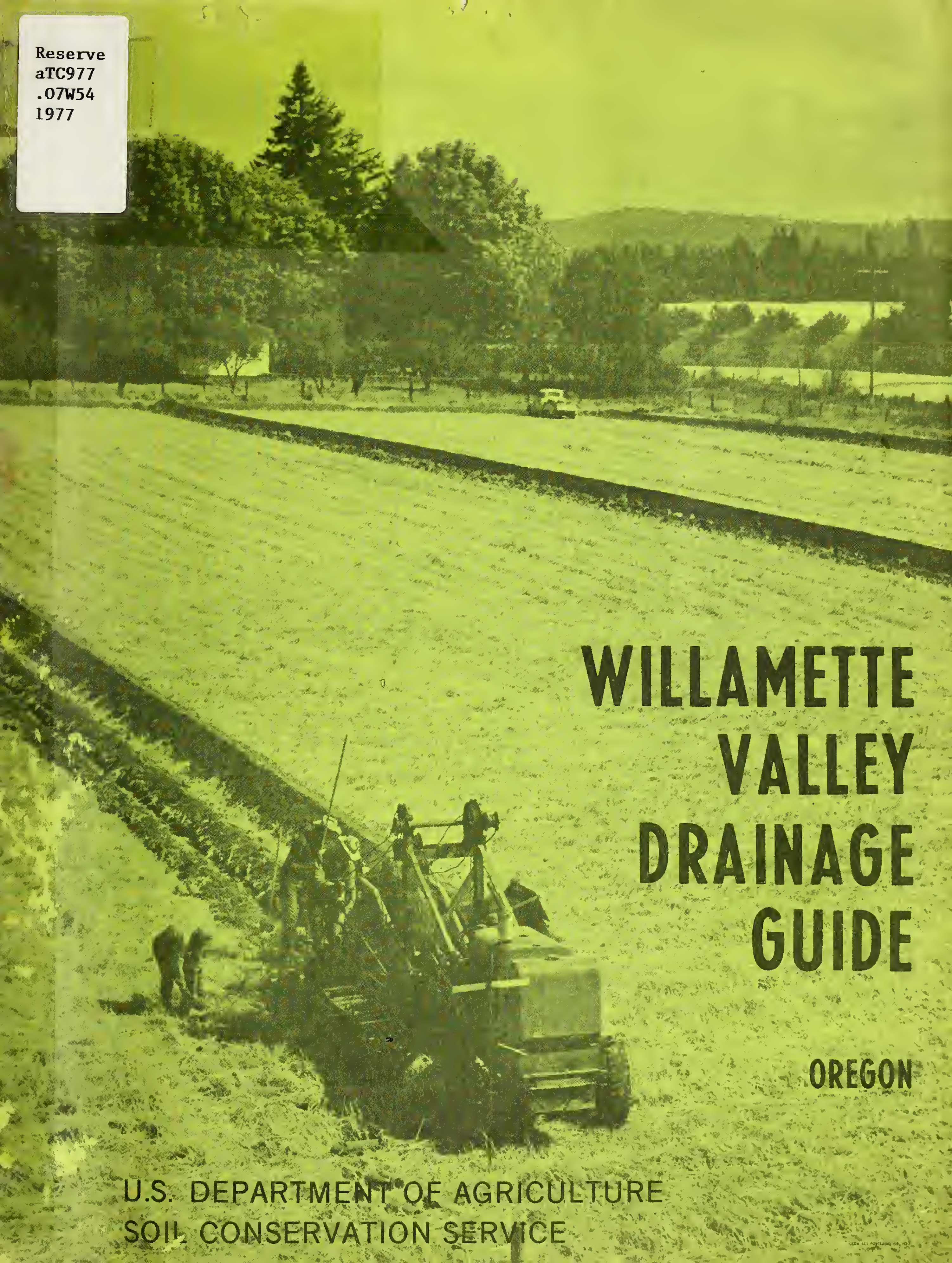

WILLAMETTE VALLEY DRAINAGE GUIDE

OREGON

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Willamette Valley Drainage Guide

Soil Conservation Service

Portland, Oregon

February 1977

PREFACE

Oregon's Willamette Basin presents many agricultural drainage problems because of its combination of soils, topography and climate. The Willamette Valley Drainage Guide has been developed to provide localized data needed to solve these drainage problems.

The development of the guide began several years ago under the direction of Merritt V. Penwell, then State Conservation Engineer, in consultation with Roy L. Fox and Ralph H. Brownscombe. Leadership in gathering data and assembling the guide was provided by Hyrum J. Woodward, General Engineering Specialist. Others assigned local responsibility for gathering data and assisting in guide formulation were Paul J. Corak, Donald W. Haslem, Forest L. Miller, Thomas T. Fujii, W. Richard Verboort, Donald L. Stettler, Norman D. Wheeler, Hubert J. Oliver, Clyde C. Bowlsby, Lynn H. Williams, George E. Otte, and Henry Clay, all employees of the Soil Conservation Service.

Valuable support and assistance has been given by the Soil Science and Agricultural Engineering Departments of Oregon State University in the form of research findings and consultation on guide development and format. Those assisting from OSU were Dr. Larry Boersma, James Schoof, Darrell G. Watts and Dr. Royal Brooks.

Final editing was completed under the direction of Donald L. Stettler. Assisting him were Joseph W. Sahlfeld and Leonard L. Gilson. Valuable assistance on editing of soil data was furnished by Rudy W. Mayko, William R. Patching, George L. Green, and Clarence A. Knezevich. The drafting and layout work was done by Gerald L. Gregory. Georgia A. Friesen provided all the typing for the numerous changes and corrections. Many others have also contributed.

It is intended that, as practices change or methods of drainage improve, these new ideas be incorporated into the guide. Each person who uses the guide is encouraged to make notes in the guide when he encounters situations that differ from those shown. These notes will aid in updating the drainage guide in the future.

ACKNOWLEDGMENT

The leadership given by Hyrum J. Woodward, former General Engineering Specialist, Soil Conservation Service, in the preparation of the Willamette Valley Drainage Guide is gratefully acknowledged. Although many have been involved in the Guide's preparation, it is his single effort which is most responsible for its completion.

The content of this guide is based upon data assembled and earlier drafts prepared by Mr. Woodward while on the State Conservation Engineer's staff between 1964 and his retirement in 1972. After 38 years of public service, he is now residing in Utah.

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INTRODUCTION

The Willamette Valley Drainage Guide is a tool to be used by engineers, field technicians, contractors, and others involved in the task of designing, constructing, operating, and maintaining agricultural drainage systems. It is divided into the following three parts:

I. General Information.

II. Technical Criteria and Data.

III. Appendices

Part I of the guide deals with background information needed to fully understand the drainage problems in the Willamette Basin. It contains a brief history of drainage developments and discusses climatic factors affecting drainage and the social and economic growth of the area. Geologic and geomorphic features and prominent arable soil characteristics of the basin are also given.

Part II deals with the solving of actual drainage problems in the Willamette Basin. It contains a summary of current design and construction practices and introduces some new concepts of system design. It lists Soil Conservation Service standards for drainage work. Also contained in Part II are Soil Association Sketch and Design Information sheets. These sheets have been developed for each soil that has a drainage problem and they suggest methods of solving the problem.

Part III contains items which can be utilized in completing a design. These include standard structural drawings, SCS forms, charts, job sheets, cost data, and other miscellaneous materials.

PART I

General Information

The purpose of Part I is to give general information concerning drainage in the Willamette Basin. Part I begins with a general description giving physical characteristics such as location, size, climate and elevation, as well as its agriculture and population. Drainage development in the basin is also examined. A brief history of drainage is given followed by a discussion of the extent of drainage, installation methods, and materials. Drainage in relation to other conservation practices and future needs in research and data collection is also discussed. Part I concludes with a general description of the basin's geology, geomorphology, and soils.

GENERAL DESCRIPTION

LOCATION AND SIZE

The Willamette Basin is located in the northwestern portion of Oregon and includes the watersheds of the Willamette River, the Sandy River, and other minor tributaries of the Columbia River from Bonneville to St. Helens. The basin is a broad, northerly sloping trough with the Coast Range on the west, the Cascade Mountains on the east, and the Columbia River on the north. The total area of the basin is 12,045 square miles, of which 11,036 square miles is drained by the Willamette River (see Figure 1). Included in the basin are Benton, Clackamas, Columbia, Lane, Linn, Marion, Multnomah, Polk, Washington and Yamhill Counties.

CLIMATE

The basin has a temperate, maritime climate characterized by wet winters and dry summers. Topography, nearness to the Pacific Ocean, and exposure to middle-latitude westerly winds are the principal climatic controls.

Basin air movement is dominated by pressure centers over the Pacific Ocean. In winter, when the pressure centers are farthest south, winds move over the relatively warm ocean surface and bring precipitation to the basin and contiguous areas. In summer, high pressure centers lie further north near the coastline and often cause the air to flow over the basin from a northerly direction. This condition decreases relative humidity and reduces cloudiness and precipitation. During spring and autumn, intermediate conditions occur causing alternate wet and dry periods.

Continental control is occasionally experienced for short periods, particularly in midsummer and midwinter, resulting in east winds and clear skies.

Temperature. Because the basin is largely dominated by maritime air from the Pacific, both annual and daily temperature ranges are relatively small. The mean valley temperature ranges from a low of 40°F. in winter to a high of 67°F. in summer. The hottest day of record has been 110°F., and the coldest -24°F. There are 250 frost-free days in the lower valleys and 160 in the higher valleys.

Precipitation. Since moisture-laden winds are from the southwesterly direction, precipitation is highest on the uplands facing southwest and least in the rain-shadow lying to the northeast of these uplands. Figure 2, Precipitation Map, Willamette Basin, shows the wide variation of precipitation within the area.

Relatively high annual precipitation occurs on the Coast Range and Cascade Mountains, reaching values in excess of 200 and 140 inches, respectively. The valley floor lies in the rain shadow of the Coast Range and Calapooya Mountains and is characterized by lesser amounts of annual precipitation varying from 35 to 50 inches.

At low elevations, most of the precipitation occurs as rain. Snowfall in the valley areas of the Willamette Basin averages less than five inches annually with no snowfall occurring some winters.

Precipitation is distinctly seasonal in character. On the average, 25 percent occurs in the fall, 45 percent in the winter, 25 percent in the spring and only 5 percent in the summer. This seasonal distribution accents the drainage problem, particularly in the low-lying areas with heavy soils and poor natural surface drainage.

RUNOFF AND GROUNDWATER

Runoff. Much of the streamflow is produced on the higher, forested portions of the basin. The area above 1000 feet elevation comprises 60 percent of the basin, receives 70 percent of the basin precipitation and produces 80 percent of the basin runoff.

Streams carrying runoff from the upper basin areas are subject to periodic overbank flooding when they emerge into the lower, flatter, open valleys containing the agricultural lands. This flooding increases the drainage problem on the agricultural areas. Land inundated by overbank flow is limited in use to crops which are tolerant to sustained periods of flooding or to crops that will mature between periods of flooding.

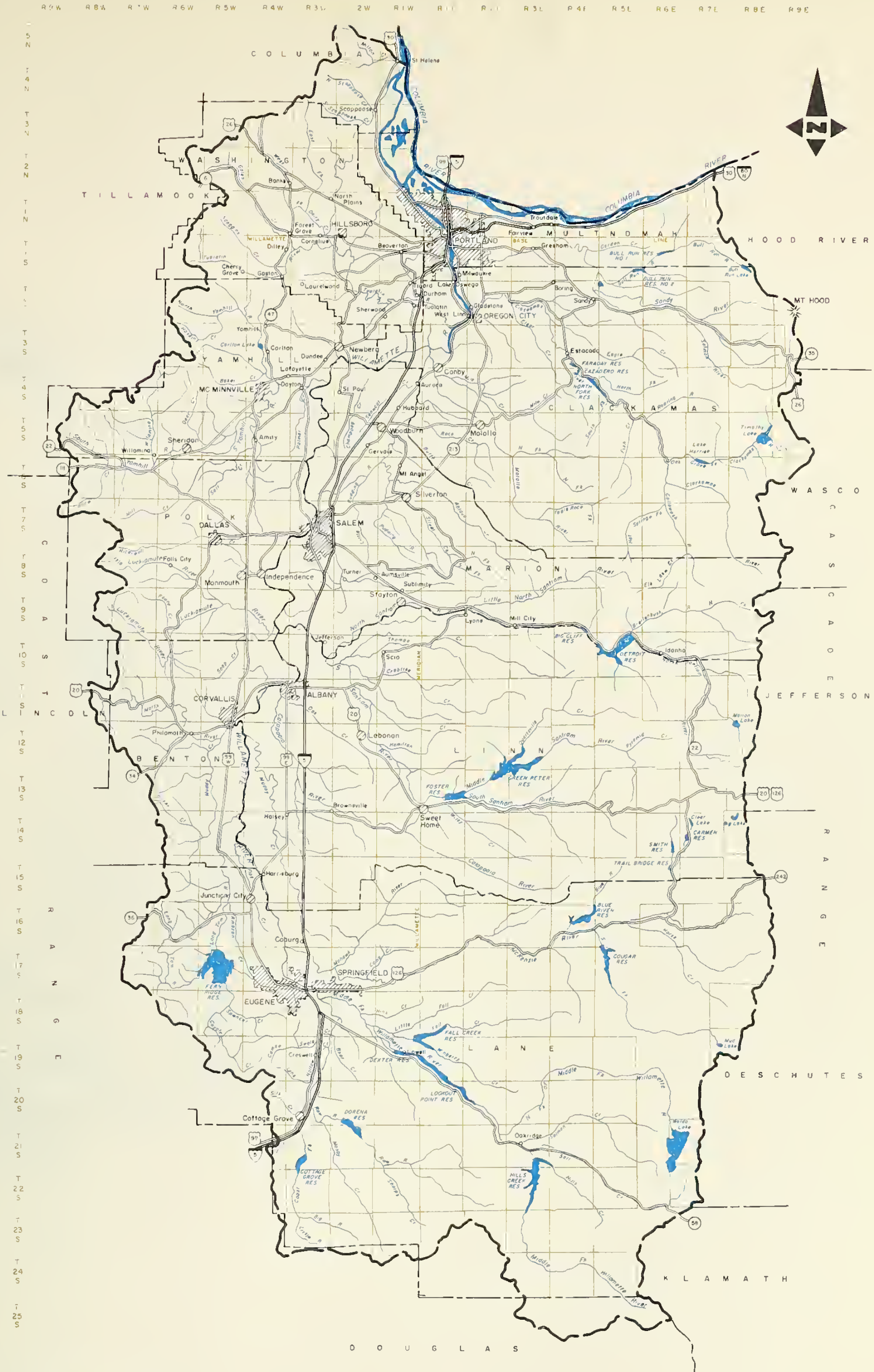
Groundwater. In some parts of the basin, deep groundwater is available in quantity for domestic and irrigation development. These sources of water have little, if any, effect on the drainage problems in the basin. However, shallow groundwater sources sometimes contribute to the drainage problems by rising to the surface at the contact lines of soil changes. This occurs where less permeable soils underlying the topsoils rise to the surface to block the passage of shallow flows.

ELEVATION

Elevation of lands within the basin varies from a few feet above sea level near the Columbia River to 11,245 feet at Mt. Hood in the Eastern Cascades. Elevations of the Coast Range vary from 1000 to 3000 feet with the highest peak reaching 4100 feet. The agricultural land lies mostly within the Willamette trough at elevations below 1000 feet. Valley floor elevations range from 350 at Eugene to about 20 at the Columbia River.

POPULATION

The population of the Willamette Basin was 1.45 million in 1970. Of this total, 77 percent was urban and 23 percent rural. Less than 6



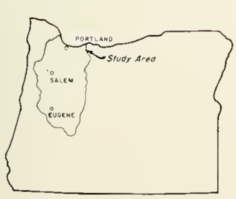


FIGURE 1

WILLAMETTE RIVER BASIN

OREGON

JANUARY 1977

5 0 5 10 15 20 25 MILES

SCALE 1:1,400,000

Source:
Prepared by SCS Portland Cartographic Unit from Willamette Basin Comprehensive Study, 1969.

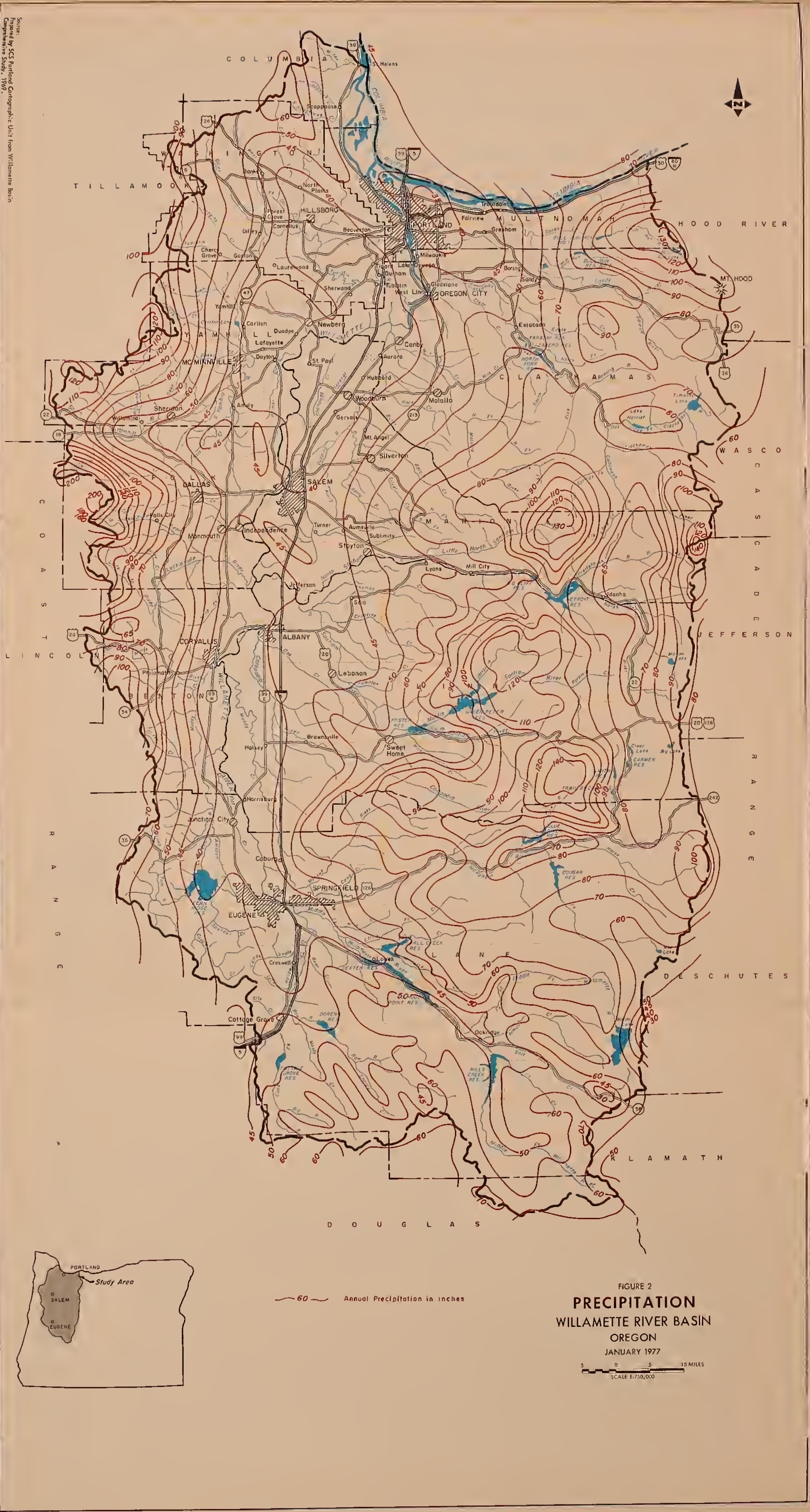


FIGURE 2
PRECIPITATION
WILLAMETTE RIVER BASIN
OREGON
JANUARY 1977

Source:
Prepared by SCS Portland Cartographic Unit from Willamette Basin Comprehensive Study, 1969.

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percent of the basin population resided on farms. The percentage of urban dwellers was highest in the lower basin near Portland while the percentage of farm population was lowest. The percentage of urban population was lowest in the middle Willamette area and the farm population highest. The highly industrialized areas at each end of the basin are the primary cause for the higher percent of the population being urban.

Some 69 percent of the population of the State of Oregon lives within the boundaries of this basin; 42 percent of Oregon's population is concentrated in the lower basin area which includes the Portland metropolitan area.

AGRICULTURE

Soil and climatic conditions of the Willamette Basin are favorable for a diversified agriculture. The land base for present agriculture consists of about 1,307,000 acres of cropland, 406,000 acres of farm woodland and some 314,600 acres of other farmland. The major use of cropland is the production of small grains, forage crops and grass seed. The more intensive crops such as fruits, nuts and vegetables account for a minor part of cropland acreage but are important sources of farm income. A considerable amount of farmland has been shifted to other uses, such as residences and roads, but the acquisition and land clearing by farmers for agricultural use has tended to compensate for this loss.

There are 14,900 farms in the basin. The average size is 136 acres. Of the 8,400 commercial farms however, the average size is over 200 acres. These commercial farms contain 80 percent of the total farmland. Farm numbers are decreasing, and farm size is increasing. In the vicinity of the larger cities, the number of part-time farms is increasing.

Nearly 207,500 acres are presently irrigated in the Willamette Basin. Major irrigated crops are pasture, hay, vegetables and fruits. With some exceptions, the irrigated land is located along or near the main stem of the Willamette River and its major tributaries.

DRAINAGE DEVELOPMENT IN THE VALLEY

HISTORY

Settlement of the agricultural lands of the Willamette Basin began in the 1840's. By 1855 almost all of the readily usable agricultural lands in the valley had been taken up under Donation Land Claims.

The condition of the soils in the valley at the time settlement began is described by John M. Bloss, President of the State Agricultural College and Director of the Experiment Station. In Station Bulletin 26 dated May 1893. Mr. Bloss said:

> "I suppose, from what I have heard from those who came to this country in the early fifties (1850's) that a large portion of the soil was then in the same mechanical condition as that which may now be seen, where it has neither been cultivated nor trampled by horses and cattle. The soil was then very loose, and old citizens have told me, and I have no doubt about the truth of the statement, that they could push a walking-cane down into the ground two or three feet without any particular effort."

With the development of farming on the valley floor, farmers learned that crops could even be grown on the heavy soils, such as Dayton or Amity, by shaping the fields into "lands" or "beds" separated by surface ditches at intervals of 60 to 70 feet. Many shallow, surface outlet ditches were constructed to carry water away from large areas of the heavy soils. In some communities, farmers joined together to construct common outlets. Surface drainage of the lighter soils using open ditches was also a common practice.

It was soon apparent that the removal of surface water alone would not provide full drainage benefits and that subsurface drainage systems of clay tile or pipe would be a good investment in many localities. The clay tile industry developed in the eastern states before 1840 and had found root in the midwest shortly thereafter. In 1870 the first clay tile factory was established at Scholls in Washington County. This plant has operated continuously since that time. There are six clay tile factories in the Willamette Basin which have operated over fifty years. The first clay tile was installed near Scholls in 1872.

Most of the poorly drained valley floor soils were farmed as systems of "beds" until the 1930's when rye grass and other wetland grasses replaced alsike clover, oats, and other grains. As the grass seed industry developed, "beds" were leveled because they interfered with the operation of heavy power equipment.

Conflicting reports exist as to the number of community-type drainage projects which have been developed. Many parts of the valley are served by outlet ditches constructed or improved by joint effort. Many of these are now considered as natural stream channels. Probably farmers joined together to complete construction work and after completion any semblance to formal organization was forgotten. Ditches or channels that were self-maintaining served well; others lost most of their effectiveness because of lack of maintenance.

EXTENT OF DRAINAGE

In the past 35 years an intensified interest in drainage has developed. The inclusion of cost sharing payment under the Agricultural Stabilization and Conservation Service's programs has been a contributing factor. Drainage improvement is a major phase of the work programs of the Soil and Water Conservation Districts in the basin. Technical assistance from the Soil Conservation Service and cost sharing available from the Agricultural Stabilization and Conservation Service for individuals and groups has aided in the application of these district's drainage programs.

There is very little factual historical information about the extent of early drainage developments in the valley. Consequently, the total amount of drainage work completed since the settlement of the valley is not known. Since the inception of incentive payments for drainage, records have been kept and the progress made in the latter years is known. The following records are available for the period 1937-1964 1/:

	1937-1959	1959-1964
Total Acres Drained	376,000	56,000
Annual Amount Acres	17,100	11,200
Open Drains	10,600	4,400
Closed Drains	6,500	6,800
Feet Tile, Total	39,580,000	13,645,000
Feet Tile, Annual	1,799,100	2,729,000

The accomplishment records of the SCS for mid 1962 to 1966, a period of four and one-half years, disclose that the annual rate of installation for tile drains continued at 2,730,000 feet per year. By 1970 it had increased to 3,346,000 feet. During the 1962 to 1966 period, 214,171 feet or 47,600 feet annually of field ditches, and 1,349,763 feet or 299,941 feet annually of surface drainage mains or laterals were constructed. In 1970, 60,760 feet of field ditches and 300,000 feet of mains and laterals were constructed.

1/ Willamette Basin Comprehensive Study, Appendix G, page II-50; Willamette Basin Task Force, PNWRBC, 1969.

While the annual extent increased almost one million feet or 52 percent for the average amounts shown in the above tabulation, the acreage of tile drainage only increased 300 acres or five percent. This indicates that more tile is being placed per acre, i.e., at a closer spacing between lines. This is the result of more intensive cropping patterns in the valley which require a higher degree of drainage.

During the past 30 years, the further development and increased availability of tile laying equipment has spurred the shift from open drains to closed drains. In the past few years, 90 percent or more of drainage construction expenditures has been used on subsurface drainage. Farmers prefer closed drains because they allow more efficient farming, require limited maintenance, and take no land from production.

The extent of land needing drainage as listed 2/ below indicates that the drainage job is only 36 percent complete as of 1969.

Drainage Problem Area	-	Acres	1,310,000 Total
Land Drained to Date	-	Acres	466,000
Land Needing Drainage	-	Acres	844,000

There is a discrepancy betwen the acres of drains reported installed since 1937 and lands drained to date. This can be accounted for in several ways: (1) the area in acres drained includes areas which are not considered as needing drainage as estimated by the Willamette Basin Task Force and (2) the drains as installed on a considerable acreage were not effective or are inoperative at the present time.

The lack of adequate outlet systems has limited the development of successful drainage on a considerable acreage. It is expected that an increase in community-type drainage work will take place in the future. Under the Resource Conservation and Development and Small Watershed projects in the south valley area, a number of group drainage jobs are being planned or constructed at the present time.

INSTALLATION METHODS

Installation methods have changed drastically since the inception of drainage improvements over 100 years ago. The first drainage work consisted of hand excavated open channels to relieve surface flooding or ponding. This was later improved upon using horse-drawn scrapers, plows, or ditchers of crude design and construction. When steam engine power became available, machines were developed to utilize this power on floating dredges or land excavators. Dragline or clamshell buckets powered by steam were used on dredges to open Lake Labish drainage channels in the 1890's. The development of the internal combustion engine further spurred development. Today, many types and sizes of power equipment for open channel excavation are available.

2/ Willamette Basin Comprehensive Study, Water and Related Land Resources, Appendix G. Land Measures and Watershed Protection, pages III-15 to 18; Willamette Basin Task Force, PNWRBC, 1969.

Excavation, placement of tile, placement of blinding and filter materials and back-filling were done by hand for many years. About 1900 the wheel-type trench excavator was developed. They were first powered by steam and then gasoline and diesel powered units. Variations from the trench excavator have been made, but most tile drainage is still installed in trenches excavated with the wheel excavator. Placement of tile varies from job to job; some tile is still placed by hand in machine excavated trenches. Machinery which automates the placement of drain tile and tubing is now available. In recent years, laser guidance systems have been developed to maintain grade and alignment.

MATERIALS

Open Ditch Structures. Structures in open ditches are constructed of concrete, sheet metal, pipe or timber. They can be prefabricated or built on the site. Structures regulate the flow of water into and within the drainage channels to prevent erosion and to control water surface elevations.

Corrugated metal pipe is used in drainage systems for vehicle or animal crossings or as inlets for surface water from adjacent lands. These structures are simple and economical to build.

Drains. Subsurface drains are now being laid using a greater variety of materials than ever. The oldest stable material is (vitrified) clay tile which is available in sizes from 4 to 12 inches. Concrete drain tile in similar diameters is being used. Concrete pipe, either reinforced for crossings or non-reinforced for drains, is also used. Plastic materials have been introduced in recent years. Perforated polyethene corrugated tubing in now being produced locally and has experienced a rapidly expanding market.

Filter Materials. Filter materials are used on some subsurface drain installations. In the past, wood chips, shavings, sawdust, straw and similar materials were used for enveloping tile lines. Because of recent substantial increases in cost, these materials are not extensively used now. Sand and gravel filters are used on some jobs but the cost is quite high. A filter "sock" is now produced for installation with plastic drain tubing.

Quality of Materials. Quality of clay tile, concrete pipe or tile, plastic pipe and tubing, bituminized fiber pipe, corrugated metal pipe or other materials used in drain construction has improved considerably over the years. At the present time, rather uniform high quality materials are being used in construction. This material quality is covered by ASTM standards and specifications and by other standards issued by private or governmental agencies. The pertinent material specifications are listed in the SCS Practice Standards and Specifications now in use, which are:

Code No.	Title
606	Drain
608	Drain System Structure

Economics of Drainage. Drainage costs and dollar return on drainage investments vary with the soil being drained, the amount of drainage work needed per acre, and the type of materials used in the installation. Costs increase in proportion with the intensity of drainage installed. Truck crops or fruits often require intensive drainage to improve productivity and may yield a high return on drainage investments. Other crops grown on less intensively drained lands may also yield a satisfactory return on the investment. The proper selection of drainage materials, the use of filters and envelopes designed for the soil conditions, and the use of equipment and techniques to insure good workmanship should substantially lengthen effective life and increase net returns on the investment. Adequate outlets are needed to insure successful operation of drainage systems. The economic analysis of a drainage system must include the installation and maintenance costs of an adequate outlet.

Construction Costs. Construction costs of open ditch or closed drains vary considerably throughout the Willamette Basin. The type of drain, the materials and equipment used in construction, soils, depth of drain, location and other factors all have an impact on costs. Simple, relatively shallow tile drains requiring no special filter materials can be constructed for less than 34 cents per foot in the 4-inch size while the same size drain laid at six feet with a graded gravel-sanded filter and a number of control structures may cost at least twice as much. Average costs which are satisfactory for initial cost estimates are given in Appendix A.

If additional information is needed to prepare a cost estimate, the local drainage contractor, County Agent, or Soil Conservation Service technicians may be of assistance.

RELATION TO OTHER CONSERVATION PRACTICES

Resolving drainage problems may require various works of improvement, depending on the soils involved. Land smoothing and improvement of soil structure and tilth will take care of some difficulties. Installation of closed drains and control of floodwaters will prevent much of the waterlogging. Improvement of present open channels and creation of new outlets will further hasten excess water removal from all sources.

Many drainage problems are closely associated with flood problems, and the elimination of prolonged flooding is often a prerequisite to a successful drainage system. In most cases, this surface water disposal can best be classified as flood control. Surface drainage may be required however, when local ponding occurs.

Flood control on the major tributaries is progressing slowly. Flood control and multiple-purpose reservoirs on the major tributaries in the basin now provide about 1,700,000 acre-feet of storage for reducing peak flows and for municipal, industrial, and agricultural uses. Even with the control now provided, about 130,000 acres of land in the valley flood at least once annually. There are potential sites for the

economic development of about 4,000,000 acre feet of additional storage which if constructed would substantially reduce all flood events.

Major flood control measures, however, will not control all flooding. Small uncontrolled watersheds will still contribute water to the drainage problem in the lower lands. An adequate local outlet system is essential for the removal of this floodwater. Figure 3 shows community outlet drainage problem areas. 3/

RESEARCH NEEDS

Research is needed to resolve some design and installation problems of drainage systems in the basin. The following is a discussion of some of these needs.

Filter Materials. Field observations indicate organic filter material is very effective, at least for some time after being installed. Research is needed to determine the effect of depth of installation on permeability characteristics of the different filter materials. The permeability characteristics should be determined quantitatively and design criteria developed for the thickness of the envelope for each organic material. The effect of aging on the permeability characteristics should be determined.

Field evaluations of some existing tile systems in which organic materials have been installed is reported in the publication "Report on an Evaluation of Tile Drains Laid with Organic Blinding Materials, Skagit SCD Washington", prepared by R. D. Brownscombe, E. W. Cowley, and R.R. Tuttle, May 1959, USDA-SCS. Most of the materials investigated in compiling the above report were still effective.

Research should be conducted to determine in which soils designed gravelly sand and gravel filters are needed to prevent the finer materials from moving into the drain line. This research should also determine the grading of the filter materials for each soil type.

Conduit Material. Research on conduit material has been carried out on the Jackson Farm near Corvallis by Oregon State University scientists. Small diameter, two to three-inch, semi-ridged, thin walled, plastic drain lines have been installed and performance has been measured. Their performance is now being evaluated and once this is completed the results will be published.

3/ Map presented as Map II-12, Community Outlet Drainage Problem Areas, Willamette Basin Comprehensive Study of Water and Related Land Resources, Appendix G, Land Measures and Watershed Protection; Willamette Basin Task Force, Pacific Northwest River Basin Commission, 1969.

Backfill Methods. Research is needed to resolve some special problems when the soil originally excavated from the trench is used for drain blinding and backfill. Most soils are stratified, some more than others. Structure changes may be rather pronounced from strata to strata. Not all soil strata are suitable blinding or filter materials. Surface strata are generally more acceptable for blinding than sub-strata. Intermixing of strata may produce a backfill material which is not suitable. This is the case with some soils in the Willamette Valley and where this is known, surface soils are or should be separated for use as initial fill and envelope or filter material.

It is anticipated that if research resolves the question as to which soils need filters, that many of the questions concerning backfill will also be answered.

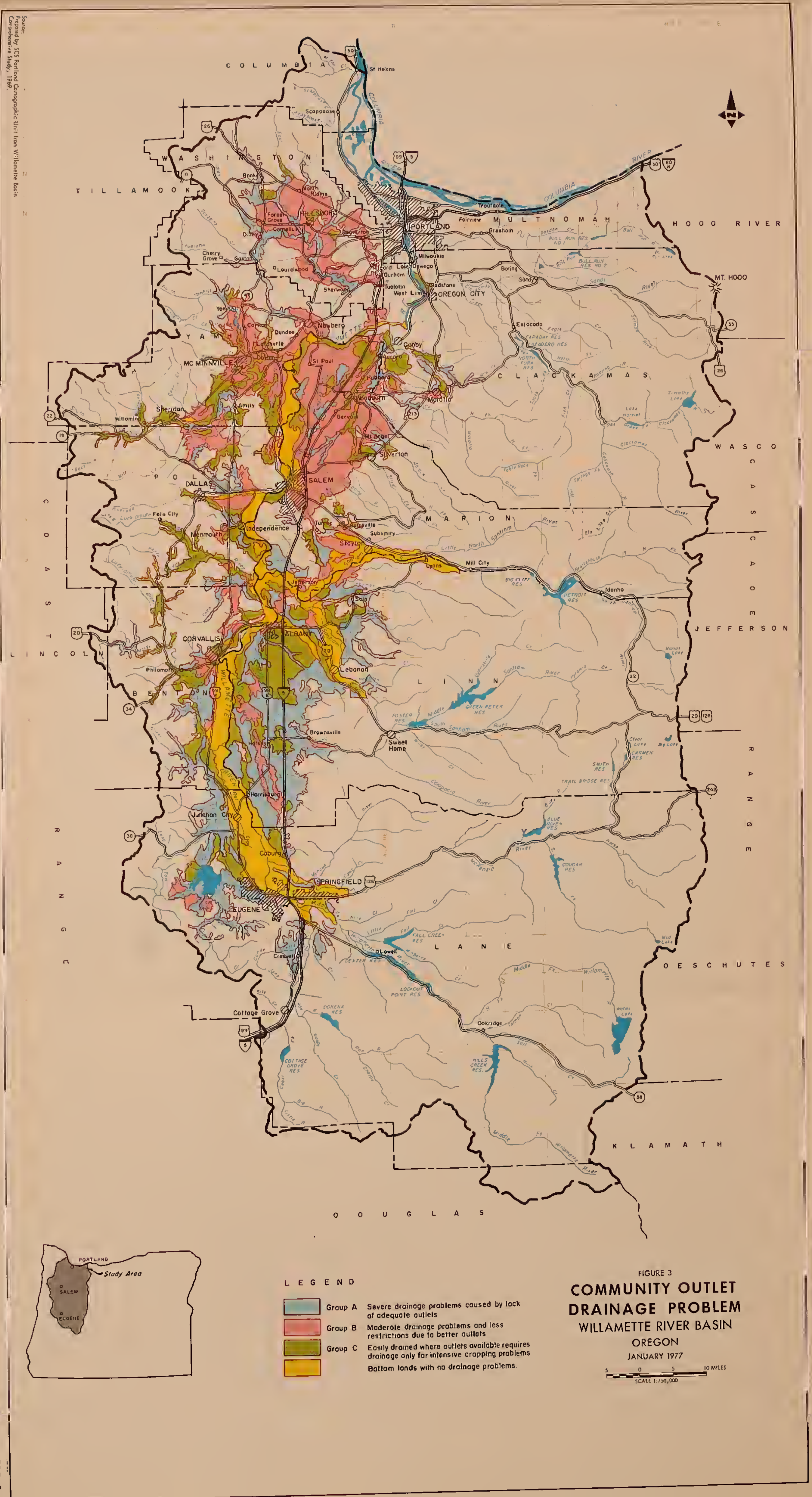
Management of Poorly Drained Soils. Many acres of poorly drained soils such as Dayton, Holcomb and similar types have not responded to drainage because of their shallow depths and low permeability. Dayton, the most predominant soil of this group, has a claypan at 16 to 22 inches below the surface. In some localities at depths of 40 to 50 inches, Dayton is underlain with Willamette silt which has moderately slow permeability. The Research Needs Report 4/ recommends investigation of methods of draining these soils by (1) altering the soil profile, (2) land treatment, and (3) drain installations. Information is lacking on the performance of drains located in Dayton or Holcomb soils as well as the long term effects on such claypan soils. Alteration of the profile by vertical mixing of organic materials and more permeable soils with the claypan materials may be the quickest means of improving permeability of these soils.

DATA COLLECTION NEEDS

Some of the data needed for the adequate design of drainage systems has been collected but there is an urgent need to continue the data collection in four areas.

Drainage Coefficient. The drainage coefficient is defined as the rate of water removal expressed in inches per day. The drainage coefficient and the area served above a specific point in a system determines the average rate of flow which must be carried by the drain at that point. In the Willamette Basin, drain systems are generally designed to handle at least three-eighths inch of water per day. For speciality or high income crops, drainage systems are designed to handle one-half to one inch of water per day. Research on plant tolerance to high moisture levels, surface inundation, and in-place hydraulic conductivity should be aimed at refining the drainage coefficient for each soil and/or crop.

4/ Soil and Water Conservation Research Needs Report, SCS, Oregon, 1963.



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Hydraulic Conductivity. Hydraulic conductivity measurements have been made at very few soil sites in the Willamette Valley. Spacing of drain lines as shown on the Soil Association Sketch and Design Information Sheets of the guide is the result of trial and error over a period of many years. Formulae using hydraulic conductivity for determining drain spacing have not been widely used. Some research has been completed by Oregon State University on the hydraulic conductivity of the Woodburn soils. 5/ Some measurements of hydraulic conductivity have been made by Soil Conservation Service personnel on other soils. These utilized current field test procedures but as yet are not in sufficient number to be used effectively in system design.

Measurements of hydraulic conductivity on Willamette, Woodburn, Amity, Dayton and Concord soils show that the initial rate of movement of water through these soils is much higher than previously estimated. When the montmorillonite clays in the lower horizons begin to swell, the conductivity reduced rapidly. Research and testing are needed to evaluate test procedures and to secure basic data in quantity sufficient to establish usable rates. Evaluation of existing effective closed drain systems should be made to check the adequacy of formulae which could be used to determine spacing of drain lines.

Filter Materials. A list of usable filter materials should be compiled. This compilation should provide sources of materials for testing under the research program previously discussed for filter materials and should publish the results in a form usable to field technicians.

Evaluation of Existing Systems. Evaluation of existing drainage systems is needed as a means of determining the effectiveness of the system in providing the degree of drainage needed. Very little work has been done in adequately and completely evaluating a drainage system. The evaluation should determine the amount of rainfall occurring during the period in question, the surface inflow to the area, the volume of water draining from the area and the maximum and average rates of flow. The effectiveness of each component of the system should be determined; i.e., bedding, land grading, field ditches, mains or laterals, drain lines and appurtenant structures. The evaluation should show any observable effects of prolonged flooding or ponding on plant growth and yields.

5/ Results of a Drainage Investigation of a soil of the Woodburn series, Special Report 162, September 1963, Agricultural Experiment Station, Oregon State University, Corvallis, Oregon.

IRRIGATION

Irrigation is needed on the cultivated crops grown in the Willamette Basin to provide the moisture necessary to sustain and improve yields. The need varies from year to year but in all years some irrigation is needed.

Historically, irrigation has been considered a supplement rather than a necessity for most crops. Actually the average moisture needs of the irrigated crops grown in the basin is about three times as great as the effective rainfall during the growing season. This suggests that rainfall is the supplemental supply and irrigation is the principal source of moisture needed for optimum plant growth. The average consumptive use requirement of irrigated crops 6/ grown in the basin is about 22.7 inches; of this, 6.2 inches is supplied by rainfall and the remaining 16.5 inches must be furnished by irrigation.

Most of the 1,310,000 acres of drained or drainable land should be irrigated after the drainage improvements are made. Lack of irrigation water on drained lands may result in serious reduction of yields. Irrigation, along with other cultural practices on drained lands, helps improve soil structure, provides better environment for soil biological activity which helps to improve tilth, and maintains the moisture levels needed for sustained optimum plant growth which is necessary for improving yields.

In the Willamette Basin, most irrigation water is applied by rotating sprinklers. Sprinkler systems should be designed to fit the soils and the crops being irrigated. Heavy textured soils are prevalent in the basin and systems on these soils should be designed to apply water at rates below the lowest intake rate of the soil. Efficient irrigation water management practices should be utilized in the irrigation of drained soils. Application rates generally exceed the drainage ability of the subsurface system so any uncontrolled excess of irrigation water may cause damage to the crops.

6/ Consumptive Use and Net Irrigation Requirements for Oregon, Circular of Information 628, Agricultural Experiment Station, Oregon State University, Corvallis, Oregon.

GEOLOGY, GEOMORPHOLOGY AND SOILS

GEOLOGY

The Willamette Basin is a broad, northerly dipping trough, the axis of which roughly parallels the Willamette River. The basin has three topographic-structural provinces, which are from west to east; the Coast Range uplift, the Willamette trough, and the Western and High Cascades. The geologic features of the basin are illustrated in Figures 4 and 5.

Coast Range Uplift. The Coast Range uplift is a low-lying mountain barrier between the Willamette Valley and the Pacific Ocean. It is approximately one-sixth of the basin, with elevations ranging principally from 1,000 to 3,000 feet with the highest point being Mary's Peak which rises to 4,097 feet. The range was formed by deformation of the earth's crust which bowed the sedimentary beds and underlying volcanic rocks into a broad ridge.

Willamette Valley Trough. The Willamette Valley trough comprises the central one-third of the basin and is generally characterized by a broad, alluvial plain, broken in the northern part portion by several low ranges of hills.

The upper Willamette Valley includes wide alluvial flats, interrupted only by shallow, meandering stream courses and a few minor buttes. The valley is bordered on the east by the foothills of the Cascades, on the west by the foothills of the Coast Range and on the south by the Calapooya Mountains, a low mountainous spur that stretches from the Cascades to the Coast Range. Elevations in this section of the valley floor are from 245 feet to 450 feet, with the perimeter being about 1,000 feet.

The middle Willamette Valley is characterized by relatively level areas interspersed with areas of rolling topography and low hills. Level valley bottoms are found in the Woodburn-Molalla area, the Newberg area, and near the Willamette River and its major tributaries. Much of the valley in Polk and Yamhill counties has gently rolling topography. Hilly areas occur south of Silverton and in the vicinity of Salem. Most of the hill summits are below 1,000 feet in elevation, while the elevation of the valley floor is generally 100 to 300 feet.

The lower Willamette Valley area is divided into three general sections; the large smooth, relatively level Tualatin River Valley, the fairly level Portland area, and the gently rolling terraces and foothills of the Clackamas River drainage. Elevations of this section of the province vary from 10 feet on Sauvies Island to 850 feet on the hills near Estacada. The moderately smooth topography of the Willamette trough is broken by low, rolling hills or buttes that reach a maximum elevation of 1,600 feet. These include the Portland Hills ridge in the north, the Chehalem Mountains ridge in the south and various smaller mountains or buttes.

Western and High Cascade Range. The western Cascade Range within the Willamette River Basin is very rugged. It contains steep slopes, sharp ridgetops, and deep canyons. Elevations range from about 1,000 feet in the foothills to 7,000 feet on the highest summits. The high Cascades within the basin lie at 4,000 to 6,000 feet elevation with a few volcanic peaks rising to 8,000 feet or higher. Mt. Hood, elevation 11,245; Mt. Jefferson, elevation 10,499; and North, Middle and South Sisters; all over 10,000 feet, are all on the Cascade crest at the eastern edge of the basin. The high Cascades have been dissected by both stream and glacial action.

At least 7,500 feet of lava flows and other igneous rocks and a small amount of marine sedimentary rocks are found in this province.

GEOMORPHOLOGY

Over a considerable period of time, erosion from the mountain ranges has partially filled the Willamette Basin. The rate of erosion was influenced by the faulting and folding of the land surfaces. The highest terraces were uplifted. Remnants of these still stand. A shift in valley gradient caused an erosional cycle to begin. This cycle is still active in much of the basin.

Parsons and Balster 7/ have mapped 12 identifiable geomorphic surfaces. In addition, they note that the steep mountain slopes are still unstable and subject to erosive forces. Landslides or mass movements have changed the surface terrain in numerous locations.

The land surfaces or geomorphic surfaces they mapped are:

1. Looney
2. Eola
3. Dolph
4. Quad
5. Calapooyia
6. Senecal
7. Champoeg
8. Winkle
9. Ingram
10. Horseshoe
11. Luckiamute
12. Miscellaneous land mass movements

7/ Geomorphology and Soils, Willamette Valley, Oregon Special Report 265, Agricultural Experiment Station, OSU, 1968.

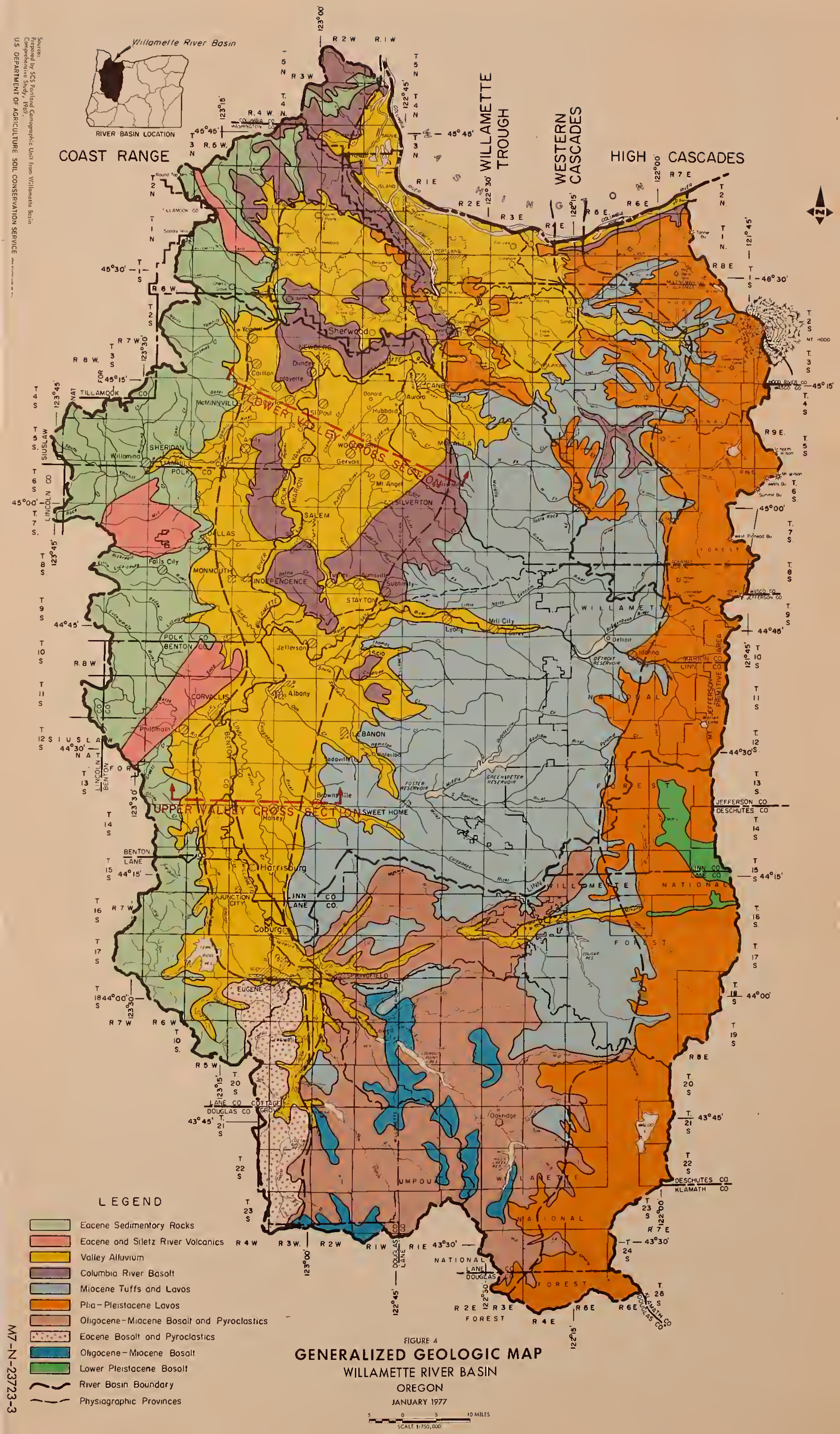
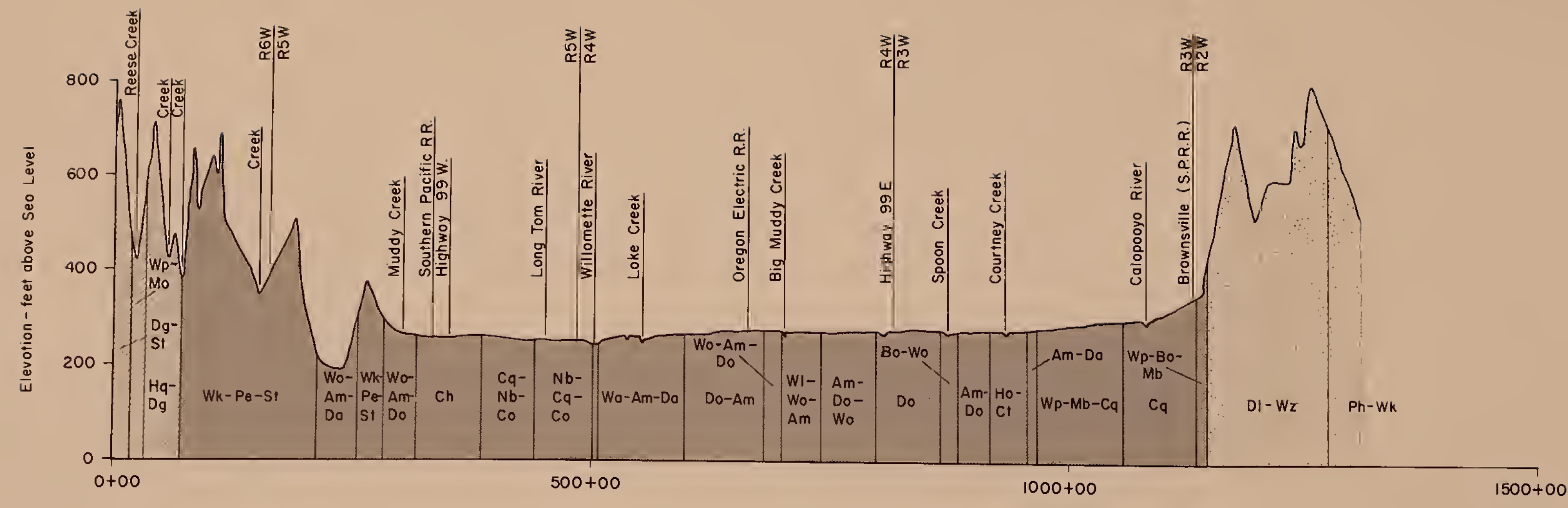
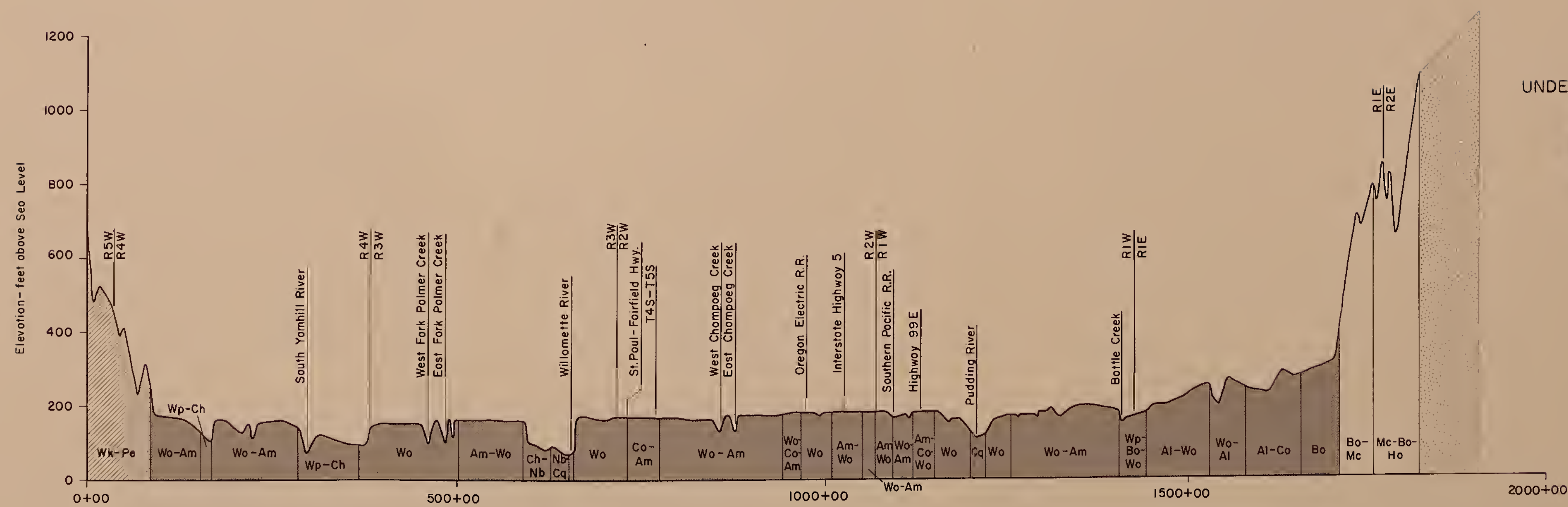


FIGURE 4
GENERALIZED GEOLOGIC MAP
WILLAMETTE RIVER BASIN
OREGON
JANUARY 1977



UPPER VALLEY CROSS SECTION

Bellfountain to Brownsville



LOWER VALLEY CROSS SECTION

McMinnville to Willhoit

LEGEND

OVERLYING SOILS

Al	Aloha	Hg	Honeygrove
Am	Amity	Mb	McBee
Bo	Bashaw	Mc	McCully
Ba	Bornstedt	Nb	Newberg
Ca	Camas	Pe	Peavine
Ch	Chehalis	Ph	Philomath
Cq	Cloquato	St	Steiwer
Co	Concord	Wa	Waldo
Ct	Courtney	Wp	Wapato
Do	Dayton	Wk	Willakenzie
Dg	Digger	Wl	Willamette
Di	Dixonville	Wz	Witzel
Ha	Hazelair	Wo	Woodburn
Ho	Holcomb		

Where two soils are shown in association the proportion of each is 70% and 30% in the order of listing. Where three soils are shown the proportions are 50%, 30% and 20% in the order of listing.

Soil associations taken from the Willamette Basin Soil Association Map. Lowlands and Foothills Profile elevations were taken from USGS quadrangle sheets.

UNDERLYING PARENT MATERIALS

- Eocene Sedimentary Rock
- Valley Alluvium
- Miocene Tuffs and Lavas
- Columbia River Basalt

Figure 5

WILLAMETTE VALLEY DRAINAGE GUIDE

SOIL POSITIONS

as shown on valley cross sections

MARCH 1977

OREGON

M7-EN-23723-4

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

The last four geomorphic surfaces were formed in rather recent geologic times, and it is sometimes difficult to distinguish Luckiamute surfaces from Ingram surfaces. The Horseshoe surfaces are generally found in the present flood plains of the major streams and their tributaries.

SOILS

Balster and Parsons list and describe the major valley soils which can be found on each of the land surfaces which they identified and named. Some soils can be found on one surface while other soils may be found on two or more surfaces. Quoting them: "Woodburn and Amity soils occur on three geomorphic units. Quad, Senecal and Champoeg...."

More complete descriptions of Willamette Valley soils may be found in the following references.

1. Willamette Basin Comprehensive Study, Appendix A, Study Area, Willamette Basin Task Force, PNWRBC, 1969.

2. General Soil Map with Soil Interpretations for Land Use Planning
   - Yamhill County, August 1970
   - Clackamas County, March 1970
   - Washington County, February 1971

   The balance of the General Soil Map and Interpretations will be forthcoming in the future for the other counties in the Willamette Basin.

3. Detailed soil survey reports of Benton, Marion and Yamhill Counties.

4. Unpublished Field Soil Survey maps in each SWCD together with descriptive and interpretative materials.

There are over 90 soil series which have been identified and mapped in the Willamette Basin. Of these, about 39 have some drainage restriction. This restriction may be due to (1) the slow internal permeability in a uniform profile, (2) the existence of claypans, compacted pans, hard pans or bedrock at relatively shallow depth, (3) the geologic and topographic location which may block drainage from a geographic area, or (4) the combination of these and other factors which cause drainage problems in soils.

PART II

Technical Criteria and Data

Part II begins with a discussion of crop drainage requirements. Included in this discussion are paragraphs on the effects of high water on crops, the level of protection from flooding, and drainage hydrology.

A discussion of drainage methods ties the current conservation engineering practices related to drainage to that particular method. Each practice is discussed in detail, including the survey, design and installation requirements.

The heart of Part II is the Soil Association Sketch and Design Information Sheets. These sheets give the localized data necessary for solving many of the drainage problems based on the soil encountered. Suggested methods of solving the problems and drain spacing and depths are given. The data contained in these sheets was developed through the success and failure of field experience. Drainage systems were constructed, operated, and evaluated. If the system was successful, the practice specifications were copied and retried. If failure occurred, the system was abandoned or modified.

Part II ends with examples of how to use the guide's technical criteria and data. These examples best illustrate the procedures currently used by the Soil Conservation Service.

CROP DRAINAGE REQUIREMENTS

EFFECTS OF EXCESS WATER ON CROPS

The growth of most agricultural crops is greatly affected by continued saturation of a substantial part of the root zone or by ponded water on the surface. Poorly drained soils reduce drop production in several ways.

1. Evaporation takes heat from the soil and lowers soil temperature. Wet soil also requires more heat to warm up than does dry soil due to the higher specific heat of water as compared to that of soil. As a result, the growing season is shortened.

2. Saturation or surface ponding stops air circulation in the soil and changes the character of bacterial activity.

3. Certain plant diseases and parasites are encouraged.

4. High water table limits root development.

5. Soil structure is adversely affected.

6. Wet spots in the field delay farm operations or prevent uniform treatment.

RAINFALL AND THE WATER TABLE

The water table may be defined as the upper surface of the saturated zone of free, unconfined ground water. The soil-moisture content for a significant height above a water table is substantially greater than field capacity. Plant root development is often restricted in the zone of saturation and when this occurs crop production may decrease.

Water tables are seldom static. They fluctuate both seasonally and for short periods. They respond to additions and depletions of ground water from natural or artificial sources. Sources such as distant influent seepage from precipitation and streamflow are seasonal, and their effects on the wet area may be delayed for months or even years. Direct precipitation and irrigation may change the water-table height almost immediately.

A study 8/ of water fluctuations involving several soils associated

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8/ Water Relation of the Soils of the Willamette Catena, L. Boersma and J. G. Collins, Soils Department, Oregon State University, Corvallis, Oregon. Published in December 1964 as a discussion paper covering a preliminary analysis of the data. Research was sponsored by the Army Materiel Command, Project No. 1-T-0-21701-A-046.

with the Willamette series has been made by the Department of Soil Science, Oregon State University. The study included the Willamette, Woodburn, Amity, Concord and Dayton soils listed in decreasing order of desirable drainage characteristics. In the Willamette, Woodburn, and Amity soils, only one water table was found under the heaviest rainfall conditions, while in the Concord and Dayton soils, two water tables developed. The upper table was perched above the claypan found in these soils while the lower one was located in the Willamette silts underlying the claypan. It can be expected that other soils in the Willamette Valley will behave in a similar manner. Some are well drained, others fairly well drained, and so on.

An analysis of available data has been made for those Oregon soils on which laboratory tests have been completed. The analysis shows the following:

Soil	Depth Sampled in Inches	Soil Water Inches per Foot		Drainage Class ***
		Capillary *	Gravitational **	
Cloquate	56	2.14	1.13	w
Peavine	63	1.64	1.04	w
Steiwer	36	2.28	1.27	w
Willakenzie	54	2.06	1.75	w
Woodburn	80	2.50	1.05	mw
Hazelair	38	1.87	0.85	swp
Dubay (now Delena)	60	2.71	1.03	swp-p
Dayton	76	2.66	0.80	p

* Water held in soil between 15 atmospheres or wilting point percentage and field capacity.

** Water contained in soil between field capacity and saturation.

*** Drainage Classes: w - well drained; mw - moderately well drained; swp - somewhat poorly drained; p - poorly drained; and vp - very poorly drained.

Unless the well drained soils, such as Willakenzie or Cloquato, were underlain at depths greater than 60 inches with impervious materials, most of them could handle rainfall from fairly heavy storms without producing surface runoff. Soil water storage above field capacity in well drained soils is moderate to very high and these soils generally have appreciable amounts of deep seepage. They can store and transmit considerable quantities of water before the soil reservoir is filled and runoff occurs. If the intensity of rainfall exceeds the surface intake capability of non-saturated soils, runoff will occur once the surface depressions are filled. On most well drained soils this occurs rather infrequently.

The moderately well drained soils act similar to the Woodburn soils. A slight fragipan or claypan occurs in these soils at rather

shallow depths. Downward flow of water through these soils is moderate to moderately fast. The deep seepage rate is slower than that for well drained soils and the gravitational water storage capacity is somewhat lower. These soils will fill easier than well drained soils and will remain saturated for a longer period. Because of these factors, more surface runoff will occur on moderately well drained soils than on well drained soils.

The somewhat poorly drained and poorly drained soils, such as Delena, Dayton, and Hazelair, have subsoils of low to very low permeability. The soil depths above these subsoils are shallow. The Delena and Hazelair soils would act similar to the Dayton. The soils become saturated soon after fall rains begin, and remain saturated during the rainy season. As a result, much of the rainfall becomes surface runoff.

OPTIMUM WATER TABLE DEPTHS

In the Willamette Basin the heaviest rainfall and the most persistent flooding occurs in the winter season. However, on the irrigated lands more water may be applied in a single day than is received during a heavy rainfall. In the summer season the excess water carried over from winter is removed by natural drainage or can be removed by constructing closed or open drainage systems. Available moisture in the soil is at about the 50 percent level when any crop needs irrigation. Enough storage space is available in the soil profile to absorb the gross amount if it is applied efficiently. Drainage facilities will remove the excess irrigation water in a short time.

Water table levels should be held deep enough to provide for the optimum root development for the deepest rooting crop to be grown. These depths are indicated in Table 1 for most crops grown in the valley. On some crops a range of depths is given to allow for varietal differences in rooting depths.

Water table depths may be affected by soil profile conditions which perch the water table above a restricting clay layer, hardpan or bedrock. Such soil conditions may limit crop growth and prevent use of deeper rooting varieties. However, intermittent hardpan or small localized areas of shallow soils should not prescribe drain depths. Drains should be constructed to the depth required for the predominant soil of the problem area. Drains laid through intermittent hardpan areas, where perched water tables develop, should be backfilled with filter or envelope material to an elevation six inches or more above the top of the confining strata. Stub or spur lines at narrower spacings may be needed in some fields to successfully drain small areas of poorer soils.

TABLE 1

Crop	Root Zone Depth (Minimum Desirable Water Table Depth) (feet)
Alfalfa	3-5
Cane Berries	4-6
Corn - Field	4-5
Orchards	6-8
Grain	4
Grapes	4-6
Flowers	
Bulb	1-1½
Seed	2-3
Grass Pasture	3-4
Hops	5-8
Ladino Clover	2
Mint	3-4
Onions	1
Nursery Stock	2-4
Truck Crops	
Beans	3-4
Beets - Table	2-3
Broccoli	2
Cabbage	2
Carrots	3
Cauliflower	2
Celery	3
Corn - Sweet	3-4
Lettuce	1-1½
Parsnips	3
Radishes	1-2
Spinach	2
Turnips	3
Strawberries	3-4
Woodland	
Douglas fir	4-6
Christmas trees	3-5

LEVEL OF PROTECTION

Rainfall accumulation or runoff must be removed from agricultural lands in order to protect crops from damage by ponding or waterlogging. Crop tolerance to excess water varies from a few hours in the case of some truck crops to several weeks for the more tolerant grasses.

An attempt has been made to determine plant tolerance to flooding. As a result, a tabulation of allowable durations of flooding has been prepared. The combined opinions of individuals working in the fields of drainage, hydrology, agronomy and economics are expressed in Table 2. Research is in progress on this subject and will continue. As better information is obtained, the table can be revised. Column 4 lists the drainage curve number to be used with Figure 6 in determining runoff rates for drainage system design.

TABLE 2

Level of Protection for Various Crops

Crop (1)	Allowable Duration of Flooding (Days) (2)	Recommended Level of Protection (Yr.) (3)	Drainage Discharge Curve No. (4)
Cereal Grain	2	5	3
Corn	1	5	2
Flowers	1	10	1
Onions	1	10	1
Truck Crops	1	10	1
Cane Berries	2	5	3
Forage	1	5	2
Grapes	2	10	2
Grass Seed	5+	2	4
Hops	2	5	3
Legume Seed	2	5	3
Mint	1	5	2
Nursery Stock	1	10	1
Orchards			
Apples-Walnuts	5+	2	4
Pears-Stone Fruits	2	5	3
Sweet Cherries-Filberts	1	10	1
Pasture, Native	5+	2	4
Strawberries	1	5	2
Woodland			
Douglas fir	1	5	2
Christmas Trees	1	5	2

DRAINAGE HYDROLOGY

General. Portions of the Willamette Basin are subjected to frequent flooding during the winter season due to the large amounts of excess rainfall. The rainfall fills up the surface depressions and the soil profile and then begins flowing overland to natural or constructed outlet channels. To provide for the orderly removal of this excess rainfall within a tolerable duration time after storm rainfall begins is the purpose for constructing open drainage systems and appurtenant drainage works on agricultural lands.

Drainage history has indicated a need for improving the procedure for estimating the rates of flow for use in designing drainage systems. Past procedures, by necessity, have had to rely on the experience of people working on drainage construction to provide estimates for flows from agricultural lands. This has resulted in some channels which were too large and in others which were too small to handle the flows which occurred.

Development of the Discharge Curves for Surface Drainage. A number of continuous recording stream gages exist on Willamette Basin streams. Six of these stations were selected as being representative of the drainable land in the Basin. The records from these stations, together with associated precipitation records, were used in determining volumes of runoff and associated flow rates for various duration and recurrence intervals. The stream flow and precipitation information was processed by the Soil Conservation Service using a computer program to develop the volume-duration-probability data. The curves on Figure 6 were plotted from this data using only the storm duration and recurrence interval combinations shown in Table 2, Column 4.

Discharge Rates for Surface Drainage. The rates of flow needed in the design of open drainage channels are determined as follows:

1. Determine the drainage area, in acres, for which the channel is to be designed.

2. Select from Table 2, Column No. 1, the desired crop. From Column No. 4, read the drainage curve number to be used for this crop.

3. Enter the chart on Figure 6 with the acreage from Step 1. Extend the acreage line vertically to intersect the curve selected in Item 2. Extend this point horizontally to the left margin and read the design flow in cfs.

Drainage Coefficients for Subsurface Drainage. In the Willamette Basin pattern drain systems are generally designed to handle at least three-eighths inch of water per day. For speciality or high income crops, drainage systems are designed to handle one-half to one inch of water per day (see Appendix D, Table D-1).

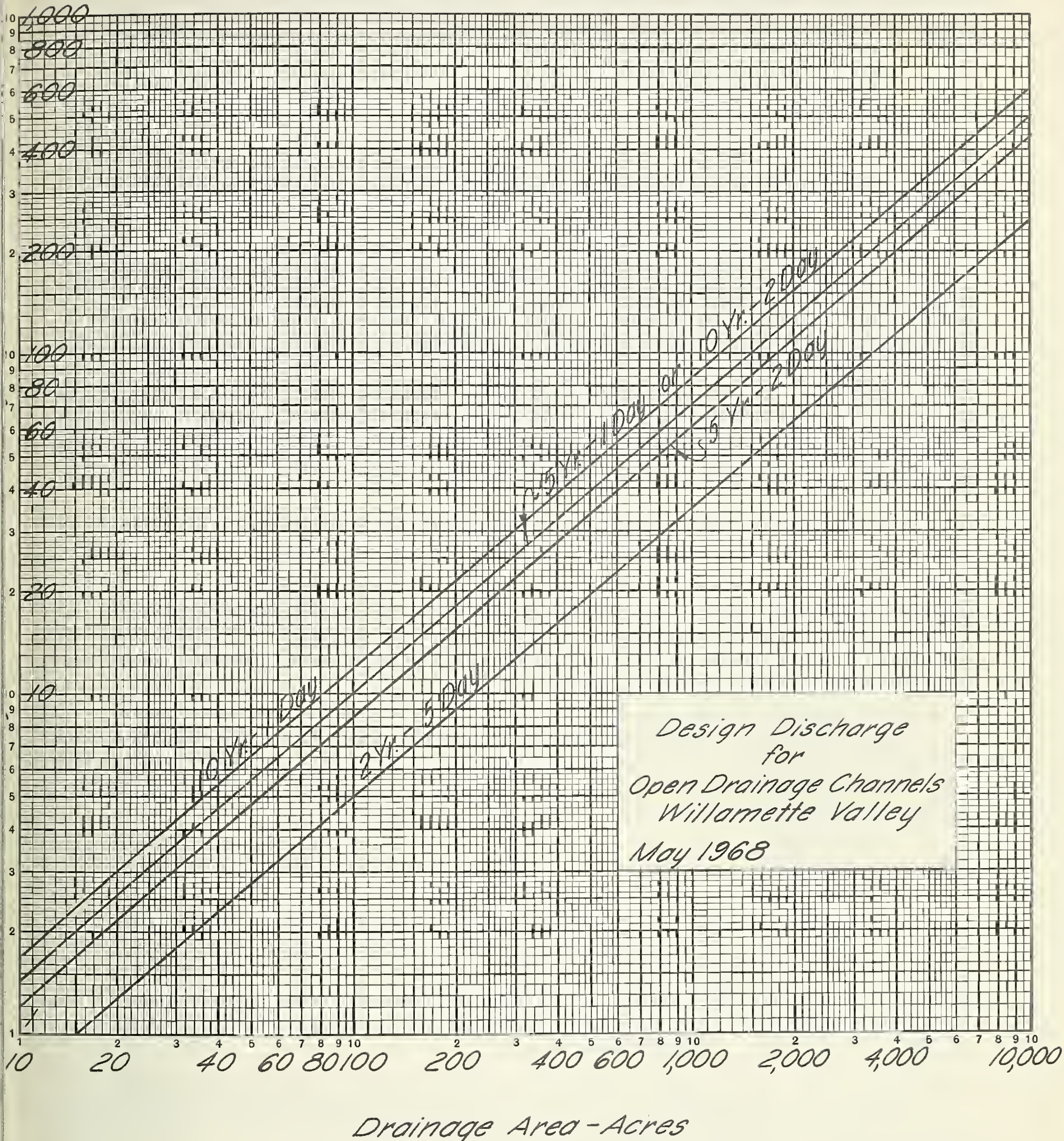

1,000
800
600
400
200
100
80
60
40
20
10
10 Yr. - 1 Day
2 Yr. - 5 Day
2.5 Yr. - 1 Day or 10 Yr. - 2 Day
5 Yr. - 2 Day
Design Discharge
for
Open Drainage Channels
Willamette Valley
May 1968
10
20
40
60
80
100
200
400
600
1,000
2,000
4,000
10,000
Drainage Area - Acres

Figure 6

DRAINAGE METHODS

Agricultural drainage may be classified into two broad categories; surface drainage and subsurface drainage. 9/ In each of these methods one or more engineering drainage practices may be used to successfully resolve the drainage problems. Engineering drainage practices include: Bedding, Land Smoothing, Drainage Land Grading, Drainage Field Ditch, Drainage Main or Lateral, Structure for Water Control, Drain, Drain System Structure, Mole Drain, and Pumping Plant for Water Control.

Good agronomic practices should be used on drained lands to maintain or improve the soil structure. The ability of soils to transmit water to drainage channels or conduits can be maintained if practices are used which do not destroy soil structure.

When any drainage problem is to be solved, the complete system of surface treatment, collection channels, disposal channels and appurtenant structures should be determined. The system should be planned for all lands which might eventually be included.

Flood control practices are also used in conjunction with drainage practices to successfully remove excess water from farm lands. Ideally, such flooding should be controlled and handled by a system of up-river storage reservoir and flood routing channels or flood control practices. Floodwater channels are not considered to be a part of the drain system, but should be planned to provide adequate outlets for future drainage systems which might be developed.

Land inundated by overbank flooding or trapped rainfall should be provided with surface drainage systems to remove the excess water. In addition, subsurface drains or open ditches are often needed to remove excess or gravitational water from the soil profile.

SURFACE DRAINAGE

Surface drainage is needed to remove surplus water from land surfaces. Surpluses result when excess water from direct rainfall occurs and surface land topography is such that water cannot readily flow to natural channels. Water may be ponded in depressions or may be flowing overland slowly in thin sheets. Drainage is necessary to reduce prolonged inundation of crop vegetation.

Heavy out-of-bank or overland flooding from adjacent streams cannot be carried by on-farm drainage systems. Flood control or flood relief systems are needed for such flows.

9/ See Drainage System Terms, Appendix B.

Open Channel - Waterway Outlet for Surface Drainage and subsurface drain lines. (Photo No. 0-3054-12)

Flow quantities to be carried by surface drainage channels should be determined by drainage hydrology procedures as outlined under the drainage hydrology portion of this guide.

One or more engineering drainage practices may be used to solve the drainage problem. Practices needed may include the following:

Land Smoothing	-	Code 466
Drainage Land Grading	-	Code 462
Bedding	-	Code 310
Drainage Field Ditch	-	Code 607-A
Drainage Main or Lateral	-	Code 607-B
Structure for Water Control	-	Code 587
Pumping Plant for Water Control	-	Code 533

These practices are outlined below and show the design criteria to be used.

<u>Land Smoothing</u>. Land smoothing is the removal of surface irregularities with farm equipment but the job does not require a complete grid survey. It is not considered as land planing or floating, but as rough grading. Land planing or floating may be needed to finish the job.

The purpose of land smoothing is to improve surface drainage or runoff, to provide more effective management of water, to obtain uniform planting depths, to provde for more uniform cultivation and to improve equipment operation efficiency.

Adequate soil depth should be available over the area to be smoothed. The grade may be determined by the equipment operator or, where required, by a partial grid topographic survey.

A uniform grade should be established which will blend into the land surface of all adjacent tilled areas. Continuous downslope should be maintained in the direction in which surface water will flow.

Construction Specifications for Land Smoothing, Code 466, are contained in the SCS Engineering Practice Standards and Specifications.

Land surface smoothness can be maintained by use of proper tillage practices. Fields may be re-smoothed by planing or floating in those years in which annual crops are grown.

Drainage Land Grading. Drainage land grading is the reshaping of the surface of the land to be drained to planed grades.

The purpose of land grading is to improve the surface drainage, to improve conditions for operation of farm equipment and to facilitate the installation of a workable drainage system for the lands to be drained.

Adequate soil depth should be available on the lands to be graded. Soil survey maps should be used for planning.

A complete topographic survey using a grid system, should be made. Grid points should be no more than 100 feet apart.

The finished slope should be uniform where practical. Slopes should be continuous in the direction of the natural land slope.

Construction Specifications for Drainage Land Grading, Code 462, are contained in the SCS Engineering Practice Standards and Specifications.

Land drainage may be maintained by planing or floating.

Bedding. Bedding is the plowing, blading, or otherwise elevating the surface of the land into a series of low ridges separated by shallow parallel dead furrows.

Bedding provides improved surface drainage by establishing adjoining parallel beds or lands running in the direction of the available natural slope. The soil is moved towards the center of the bed to form a series of ridges and dead furrows which will minimize water ponding, provide channels to remove runoff or permit easier operation of farm equipment.

The land surface should have a continuous downslope established by smoothing or grading. Shape and height of bed can be controlled by the equipment operator.

Beds should be constructed to provide a cross slope of at least 0.3 percent from the top of the ridge to the dead furrow.

Top of the bed should be at least 12 inches above the bottom of the dead furrow. Beds should not exceed 200 feet in width on shallow soils and 100 feet on deep soils.

Dead furrows should have a uniform grade from the upper to the lower end of the furrow and should outlet into a collection ditch, drainage field ditch or grassed outlet channel.

Outlets should have sufficient capacity to carry all waters transported to them by the bedding furrows. Flow quantities can be determined by using the drainage hydrology procedures shown in this guide.

Construction Specifications for Bedding, Code 310, are contained in the SCS Engineering Practice Standards and Specifications.

Bed height is maintained by plowing one way and alternating direction each year. Dead furrows or ditches should be cleaned out to allow free drainage of collected waters.

Drainage Field Ditch. Drainage field ditches are shallow graded ditches for collecting water within a field, usually constructed with flat side slopes for ease in crossing.

Drainage field ditches are used to drain surface basins or depressed areas in fields. They are also used to collect or intercept runoff from natural or graded land surfaces or channeled flow from plow furrows, crop furrows, and bedding system furrows for removal to an outlet chanel.

Topographic maps, when available, should be used in system design. Aerial photographs may be utilized for initial system layout if topographic maps are not available.

Field location surveys should be made after initial location is completed on available maps. Such surveys should include centerline locations, centerline profile and representative cross sections. All surveys should be closed to the accuracy shown in the Engineering Field Manual for Conservation Practices, Chapter 1, Engineering Surveys.

Soil surveys should be utilized in drainage design. The recommendations for field ditch spacing given in the Soil Association and Design Information Sheets of this guide should be used.

Drainage field ditches in an orchard in Yamhill County. (Photo No. 0-609-9)

Field ditches should have the capacity to carry the flows from the area served as computed by drainage hydrologic procedures established for the Willamette Valley.

Flows should be controlled so that non-erosive velocities are maintained as specified in Table C-2, Appendix C.

All appurtenant structures should be designed as integral parts of the system under consideration. Structures, as needed, should be installed concurrently with field drainage ditches.

The flow at design capacity should not back water into furrows or collection systems above the elevation needed to deliver design flows to the field ditch.

Dimensions selected should consider the type of equipment used in ditch excavation or maintenance. Dimensions should be adequate to carry the design flow with "n" values selected from Table C-3, Appendix C. Side slopes for the ditch section should be selected with the maintenance method to be used in mind, as given in Table C-1, Appendix C. The need for crossing field ditches during regular farming operations should also be considered when ditch side slopes are selected.

Construction specification for Drainage Field Ditch, Code 607-A, are contained in the SCS Engineering Practice Standards and Specifications.

Ditches should be cleaned as necessary to remove silt, debris, and vegetative materials which retard the normal flow of water. Ditches should be maintained to their original dimensions and grade, if possible.

Drainage Main or Lateral. Drainage main canals or canal laterals are open channels designed to handle flows on non-erosive grades.

The purpose of drainage main or drainage lateral is to intercept surface or subsurface water or to collect intercepted water from drainage field ditches or collection ditches. Such channels are also used to control ground water levels in fields drained by the system.

Open drain outlet for field ditches and buried tile drains. (Photo No. 0-1922-9)

Detailed surveys of the soil profile are needed to determine the depth at which drains should be located. The water table elevations and, if needed, the variation of the water table throughout a year or more should be determined. Chapter 14, Drainage, of the Engineering Field Manual discusses these surveys.

Existing topographic maps, aerial photographs, and soil surveys should be utilized to determine canal or lateral layouts.

Adequate surveys should be made to properly control design and construction. Surveys should include centerline location, centerline profile, representative cross sections and location of test holes, observation wells, or other pertinent physical features.

Drainage system capacity for canals or laterals should be designed to service all the area which may eventually use such mains or laterals. Capacity should be based on flow rates determined by the hydrologic procedures developed for use in the Willamette Valley. The most severe combination of rainfall and crop conditions which may be encountered should be used in determining capacity.

Hydraulic gradient and canal or lateral bottoms should be so located that tile or open drainage field ditches, collection ditches, outlet structures, etc., can empty into them during normal flow condition without adverse backwater conditions occurring.

Dimensions of canal or lateral sections should be adequate to carry the calculated discharge. Side slopes should be stable. Suggested side slopes are contained in Table C-1, Appendix C. Bottom widths will vary, but generally should not be less than about 3.0 feet.

Open drain – One slope flattened with spoil spread. (Photo No. 0-702-3)

Velocities of water entering and flowing through drainage canals or laterals should be controlled to prevent erosion of soil materials from the channel cross section. Permissible velocites are given in Table C-2, in Appendix C.

Where laterals are used to intercept or relieve underground water, they should be spaced according to the criteria contained in the Soil Association and Design Information Sheets of this guide.

All appurtenant structures should be designed as integral parts of the system. Structures should be installed concurrently with canal or lateral construction. Structure selection and design are contained in the section on Grade Control Structures of the guide.

Construction specifications are contained in the SCS Engineering Practice Standards and Specifications under Code 607-B, Drainage Main or Lateral.

Canals or laterals should be cleaned as needed to remove silt, debris and vegetative materials which retard the flow. Canals or laterals should be maintained to their original dimensions and grades if possible. Care should be taken not to overexcavate channel bottoms.

Drainage ditch in need of maintenance work. (Photo No. 0-1220-7)

Structure for Water Control. A water control structure is used in a drainage system to control the direction or rate of flow or to maintain a desired water surface elevation.

Examples of structures used in drainage systems would include:

1. Drop, chute, surface water inlet, stilling basin.

2. Check box inlets, pipe drop inlets.

3. Screens - trash racks, rodent gates.

4. Tide or drainage gate.

5. Bridges, culverts, flumes, inverted siphons.

Centerline location, profile, and cross section surveys made for drainage field ditch or drainage main or drainage lateral will suffice to determine location of needed structures. They are needed to establish elevations of top and bottom of structures and their position in the alignment and cross section of the channel.

Structures should be designed on an individual basis utilizing, wherever possible, standard drawings. They should be designed to fit the channel and be of sufficient size to discharge the design flows.

Construction specifications are contained in the SCS Engineering Practice Standards and Specifications under Code 587, Structure for Water Control.

Each structure in a drainage system should be inspected at least once each year and any needed repairs should be made immediately. The elevations and grades of critical structure components should be maintained.

Pumping Plant for Water Control. A pumping plant for water control is a pumping facility for removing excess surface or ground water from lowlands, or for pumping from sumps, wells, ponds, streams, or others sources. In drainage, this would mean pumping from a drainage channel into another drainage channel or natural water course at a higher elevation.

Pumping plants are used to provide an outlet for a drainage system when a natural or constructed channel is not physically possible or economically feasible to construct.

Drainage system channel surveys and subsequent system design will establish the general location of the pumping plant and the elevations of the principal components of the structure. Construction surveys should establish the position of the pumping plant structure accurately in relation to the centerlines of the drainage channels.

The capacities, range of operating lifts, and general class and efficiency of equipment should be determined from adequate technical studies. The discharge requirement of the pumps should be the combined surface and subsurface flows. The total operating head should be determined for the most critical operating condition to be encountered. Wherever possible, pumping plants should be automated and protected with safety devices to prevent damage to the various components.

The design of the various components of the pumping plant should meet the general requirements of SCS Engineering Practice Standard and Specification Code 533, Pumping Plant for Water Control. Detailed information on pumping plant design is contained in Chapter 8, Section 15, National Engineering Handbook, Irrigation Pumping Plants, or USDA Technical Bulletin 1008, "Design and Operation of Pumping Plants." Services of power companies or private engineers are available for use in pumping plant design.

A regular maintenance program should be developed and followed in servicing pumping plants. Repairs should be made as needed. Plants should be inspected thoroughly at least once each year and repairs as needed made immediately.

SUBSURFACE DRAINAGE

Subsurface drainage of agricultural lands may be accomplished by using either closed drains or open ditches. Subsurface drainage removes excess gravitational water from the soil profile by (1) intercepting the path of flow and carrying the flow to a suitable outlet, or (2) providing channels into which the water can readily move for transportation to points of disposal.

One or more engineering drainage practices may be used to solve the drainage problem. Practices needed may include the following:

Drain	- Code 606
Mole Drain	- Code 482
Drainage Field Ditch	- Code 607-A
Drainage Main or Lateral	- Code 607-B
Structure for Water Control	- Code 587
Drain System Structure	- Code 608
Pumping Plant for Water Control	- Code 533

Some of these practices have been detailed under the Surface Drainage Methods. The design criteria for the balance of the practices are outlined below.

Drain. A drain is a covered drain such as tile or pipe, of suitable size, installed beneath the surface of the ground with a planned depth and grade.

Drains are installed to (1) improve agricultural production through lowering the water table, (2) intercept and prevent water movement into a wet area, (2) relieve artesian pressures, (4) remove

surface water or runoff, (5) provide an outlet for leaching water, or (6) serve as an outlet for other drains.

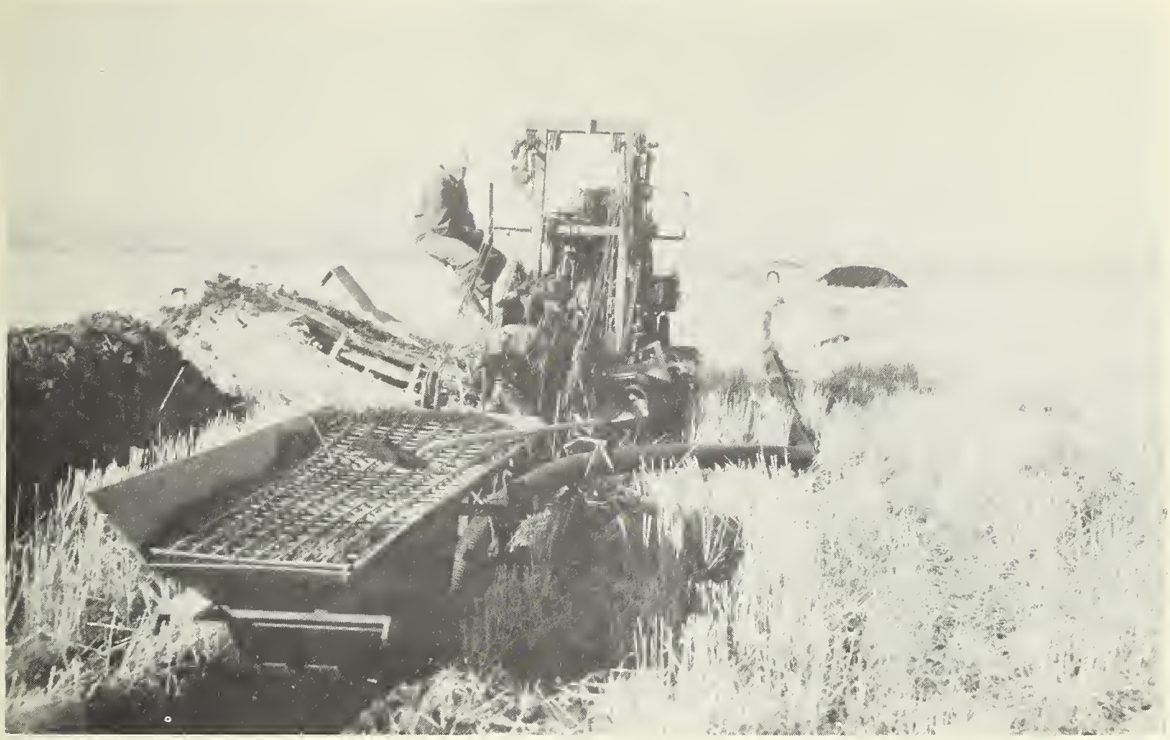
Soils maps and other soils investigations should be used to determine if the lands to be drained will be suitable for agricultural use, within their capabilities, after the installation of the needed drainage and supporting practices. The soils should have enough depth and permeability to permit installation of an effective and economically feasible system.

An outlet for the drain system should be available either by gravity flow or by pumping before a drain system is designed.

Topographic maps can be used where available for initial drain system layout. Photographic maps are also suitable for layout. The centerline should be laid out and profiles of all drain lines taken. Surveys should be of third order accuracy.

Soil profiles along drain centerlines should be determined by auger or open pit sampling. A maximum distance of 600 feet between pits or holes as measured on centerlines should not be exceeded. Information secured from soil profile sampling is useful in determining the proper depth to place the drain.

Clay tile being installed in a parallel pattern. Outlet line is at left side of field. (Photo No. 0-541-11)



Plastic tubing installed as an interceptor with crushed, light-weight basaltic tuff as bedding and envelope material. (Photo No. 0-3057-14)

Clackamas County - Six-inch clay tile, standard grade, used in main line. (Photo No. 0-1576-9)

Sighting bar used to maintain grade on wheel trench excavator. Four-inch clay tile is being placed by hand. Soil is suitable for blinding, filter and backfill. (Photo No. 0-883-11)

Linn County - Fifteen-inch concrete pipe, tongue and groove ASTM C-118 type. Used in deeper trenches or for larger subsurface main lines. (Photo No. 0-1295-6)

Concrete drain tile used in an interceptor type drain. (Photo No. 0-522-8)

The required drain capacity may be determined by one of the following methods:

1. Selecting a suitable drainage coefficient, including capacity required to dispose of surface water entering through inlets. See recommendations in Table D-1, Appendix D.

2. Estimating the yield of groundwater based upon the expected deep percolation of excess irrigation water from the overlying fields, including the leaching requirement.

3. Using survey and comparision of the site with other similar sites where subsurface drain yields have been measured.

4. Making measurement of the rate of subsurface flow at the site.

5. Applying Darcy's law to lateral or artesian subsurface flow.

6. Making estimates of lateral or artesian subsurface flow.

The required size of drains may be computed by applying Manning's or Yarnell's formula based on one of the following assumptions.

1. Hydraulic gradient parallel to the bottom grade of drain, with drain flowing full at design flow.

2. Drain flowing part full if a steep grade or other conditions require excess tile capacity.

3. Drain flowing under pressure, with hydraulic gradient set by site conditions on a grade which differs from that of the drain. This procedure should be used only where surface water inlets or nearness of drain to outlets with fixed water elevations, permit satisfactory estimates of hydraulic pressures and flows under design conditions.

The minimum size of clay, concrete, bituminized fiber, and plastic drain is 4-inch diameter. Figures D-1 and D-2 in Appendix D will assist in sizing drain lines.

The depth, spacing and location of drains must be based upon soil type, topography, groundwater conditions, crops, and outlet conditions at the site.

The minimum depth of cover of drains in mineral soils should be 24 inches and applies to normal field levels. Sections of line near the drain outlet, or sections laid through minor depressions may be shallower if the drain is not subject to damage by frost action or equipment loading, and if site conditions justify specifying other depths for a job.

The minimum depth of cover in organic soils should be 30 inches for normal field levels, after initial subsidence. Structural measures should be installed, if feasible, to control the water table in organic soils within the optimum range of depths.

In areas with no rapid siltation hazard, the minimum grades will be based on site conditions. If such a hazard exists, however, a velocity of not less than 1.4 feet per second should be used to establish the minimum grades, if site conditions permit. Otherwise, provisions should be made for prevention of siltation by filters or collection and removal of silt using silt traps, junction boxes, or manholes.

If the stability of the drain is jeopardized because of the steepness of the grade or if velocities in the drain exceed those given in Table D-2, Appendix D, protective measures must be installed. They should be specified for a job based upon site conditions, and should include one or more of those discussed.

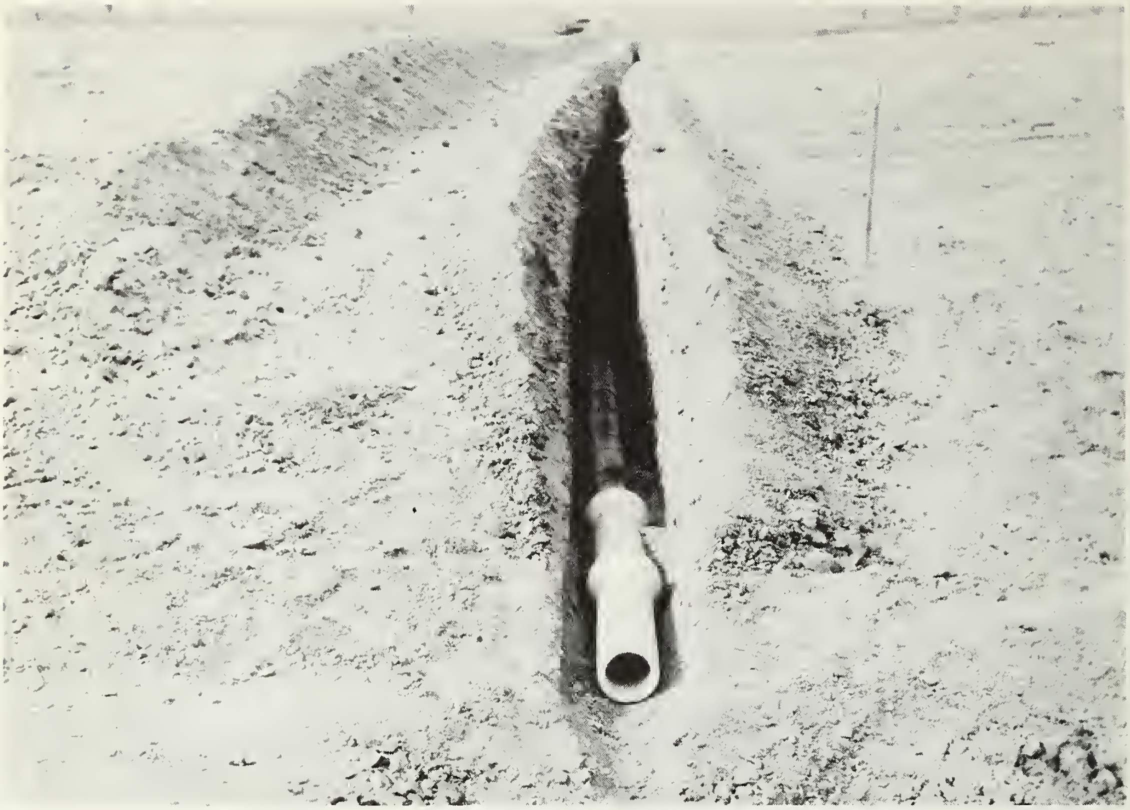
"Drains" include conduits of clay, concrete, bituminized fiber, wood, metal, plastic, or other acceptable materials that meet strength and durability requirements of the site. Current specifications of the American Society for Testing Materials, or other acceptable standard specifications, are listed in SCS Engineering Practice Standards and Specifications, Code 606, Drain.

Soft or yielding foundations msut be stabilized and lines should be protected from settlement by (1) adding gravel or other material to the trench, (2) placing tile on plank or other rigid supports, or (3) using long sections of perforated or watertight pipe.

Loads on conduits for usual tile and trench conditions should be determined in accordance with procedures on pages 4-78 to 4-81, Section 16, National Engineering Handbook. The maximum allowable depth should be computed using a safety factor of not less than 1.25. If load conditions are other than those covered by this chapter, loads should be computed in accordance with SCS Technical Release No. 5.

Suitable filter, blinding and backfill materials should be used around the drain tile and in the trench to prevent excessive amounts of sediment from entering the drain and to facilitate the collection and passage of groundwater. Backfill recommendations are shown in the Soil Association Sketch and Design Information Sheets and Appendix D of this guide.

Organic blinding and filter materials (wood shavings). (Photo No. 0-2670-11)



Two 36' lengths of concrete, bell and spigot pipe mortared to clay tile used as outlet for the clay tile. (Photo No. 0-1164-10)

The outlet should be protected against erosion and undermining, damaging periods of submergence, and entry of rodents or other animals. A rigid pipe, with suitable clearance above the grade of the outlet ditch, should be used if required by site conditions. Headwalls used for drain outlets should be adequate in strength and design to avoid washouts and other failures.

A watertight conduit, strong enough to withstand the additional load, should be used if subsurface drains cross under irrigation canals or other ditches. Conduits under roadways should be designed to withstand the expected loads. Shallow drains through depressional areas and near outlets should be protected against hazard of farm and other equipment, and freezing and thawing.

Junction boxes should be used if more than two main lines join.

If surface water is to be admitted to the drain lines, inlets should be designed to exclude debris and prevent sediment from entering the conduit. Drain lines flowing under pressure should be designed to withstand the resulting pressure and flow velocity. Auxiliary surface waterways are recommended wherever feasible.

Construction specifications for drains are contained in the SCS Engineering Practice Standard and Specification, Drain, Code 606.

Benton County - Tile drain outletting into a natural drainage channel. Note height of outlet above water surface. (Photo No. 0-798-12)

Outlets for two tile drain lines protected by flap gates to prevent entry of rodents. (Photo No. 0-1251-12)

Periodic inspections, preferably two or more times each year, should be made of all outlets, surface water inlets, sand traps or catch basins, and other auxiliary structures. Where damage has occurred, repairs should be made immediately. Trash, debris and sediment should be removed. Weeds and aquatic growth in outlets should be cut or treated with suitable chemicals. Damage to drain lines by roots, blowouts, or overloads should be repaired by digging out the drain line and restoring to original grade and condition. Drain lines in which sediment accumulates should be flushed out periodically. Screens should be inspected often and cleaned or repaired as needed.

Drain System Structure. A drain system structure is an auxiliary structure to a subsurface drainage system.

The principal purposes of drain system structures are to protect the outlet ends of lines, control grade and velocity, regulate flow, join lines, collect sediment and debris, provide access for inspection, prevent erosion, regulate water table levels, and relieve hydrostatic pressures. Typical structures used are pipe drops, headwalls, junction boxes, surface water inlets, manholes, catch basins, sand traps, relief wells, and special design structures.

The number, type and size of structures needed are generally determined during surveys and design of drain line. Soil borings should show need for special foundation design.

Structure installed in drain lines should not restrict the flow in the system. They should have a capacity not less than the line or several lines feeding into or through them. Where the drain system will carry the entire surface flow, the water inlets should have a capacity determined by using the hydrology procedures as developed for the Willamette Valley for the drainage area served by the inlet. In irrigated areas, this may include an allowance for irrigation return waters. Open channels or waterways should be designed in conjunction with drain systems to carry a portion of the runoff wherever feasible.

The capacity of the relief well system should be based on the flow from the aquifier, the well spacing, and other site conditions.

The size of junction boxes, manholes, catch basins, and sand traps should be based generally on accessibility for maintenance. Circular structures should have a minimum diameter of three feet. For square or rectangular structures, the minimum dimension should be three feet.

The size of relief wells should not be less than six inches in diameter.

The drain system should be protected against high velocities and turbulence created near outlets, surface inlets, or similar structures.

Surface water inlet structures should be equipped with screens, trash racks, or gratings to exclude floating debris. Outlet ends of drain lines should be protected by screens or gratings where necessary to prevent rodents from entering the pipe.

Junction boxes should be installed where more than two mains join or where two mains join at different elevations.

Specifications should be prepared for each type structure and should describe the requirements for installation of the structure to achieve its intended purpose.

The following plans are available for use in installing structures in tile drainage systems (see Appendix F):

Surface Water Inlet,
Standpipe, Breather or Relief Well,
Junction Box for Tile Lines,
Manhole Catch Basin and Sand Trap.

Maintenance procedures are similar to those described under the practice Drains.

Mole Drain. A mole drain is an underground conduit formed by pulling a bullet-shaped cylinder through the soil.

The purpose of a mole drain is to provide drainage for soils where the use of tile drains is physically or economically not feasible.

Soils should be tested to determine their suitability for mole drainage. A rule-of-thumb test appraising the suitability of a soil is made as follows: Squeeze a sample of soil, taken at the proposed moling depth, into an approximate 2-1/2 - 3-inch ball. Immerse the ball in a jar of water and leave undisturbed for 12 to 14 hours. If the ball remains intact at the end of this time, the soil should be suitable for moling. Soils should be examined over the entire area to be moled. Field surveys should be sufficiently detailed to determine the adequacy of outlet, location of mains, and the general direction in which the laterals should be drawn. On relatively flat or slightly undulating topography, a grid or contour map should be prepared.

Where possible, outlets should be provided by a closed drain constructed prior to the moling operation. Outlets should have a sufficient depth and capacity to provide continuous free flow. Where mole outlets may erode if left exposed, they should be protected by lining the last six to eight feet with tile or pipe. Other mole drains may be used as outlets. Outlet drains should be located at the major land surface depressions or field boundaries.

Upland surface runoff should be diverted from the proposed drainage area. The drainage area should not exceed five acres for any single mole drainage system.

Mole lines should be drawn with continuous slope toward the outlet. Land should be smoothed or leveled before moling to remove minor depressions.

Length of lines should be determined by the shape and topography

of the field and by the location of the outlets. In no case should lines exceed:

700 feet for 8 percent grades
250 feet for 1 percent grades

Lengths should be reduced proportionately between these extremes as drain grade decreases.

The mole should be drawn through the most suitable strata in the soil profile. Moles must be drawn sufficiently deep for protection against the effects of drought, frost, and loads from heavy equipment.

Spacing should be determined for the local area by trial and error. In no case should the spacing be more than 15 feet nor less than 8 feet.

The standard mole size of 4 inches should be used in clay type soils. Moles of 6-inch diameter may be used in fibrous organic soils.

The specifications for Mole Drain, Code 482, contained in the SCS Engineering Practice Standards and Specifications, should be used on all mole drain installations.

Mole drain life can be extended by limiting cultural practices affecting the land surface. Seed to adapted forage crops and limit cultural operations to an absolute minimum. Prevent rodents from establishing themselves in drained fields by an acceptable rodent eradication program.

SOIL ASSOCIATION SKETCH AND DESIGN INFORMATION SHEETS

Design aids have been developed to assist in understanding and solving drainage problems in the basin. These design aids consist of a soil association sketch and applicable drainage method(s) for each soil that has a drainage problem.

DEVELOPMENT

The soil association sketch and design information sheets were developed primarily through field experience. A list of those soils having drainage problems was compiled. Each had been given a drainage classification by the soil surveyor. These classes are moderately well drained, somewhat poorly drained, poorly drained and very poorly drained. A separate sheet was then prepared for each problem soil. The sheets are arranged under four broad headings based on the general location of the soil in the valley. These are Upland soils, Upland Transitional Zone soils, Terrace soils, and Broad Valley Flood Plain soils. An alphabetical index is included to aid in locating the individual sheets.

CONTENT

Each sheet contains a sketch which illustrates the general location of the soil in the landscape. The sketch also shows pertinent subsurface detail that affects drainage. A portion of the sheet outlines the physical factors of the soil that affect drainage. The sheet gives drainage problems found in the soil or soil association. The remainder of the sheet shows how the problem can be solved and gives the specifications for the location, depth, spacing and filter or envelope recommendations for closed drains and the side slope and maximum velocity for open drains.

LIMITATIONS

Soils. The sheet for each soil shows in the sketch only one association which might occur with this soil. A thorough knowledge of local soils is needed by each technician so that he can properly interpret the sheets and substitute other applicable soil associations as needed. When soils are renamed, the corrected name should be inserted in the proper places on indexes, sketches, descriptions, and specification sheets.

Design Criteria. Design criteria as shown on the individual sheets are somewhat limited. Values shown for drain line spacing and drain depth are those which have proven most successful in field use. A small amount of information is available on measured hydraulic conductivity. Since these measurements are on stratified soils, the information secured is not readily adapted for use on the same soil at other valley locations.

As usable hydraulic conductivity measurements are made, the values should be written on the sheet for the soil being tested. Evaluation should be made to see if such measurements, when used in the Donnan or other adapted formula, produce drain line spacings which are consistent with those now used in the successful drainage systems.

SOIL ASSOCIATION INDEX

I. UPLAND SOILS

A. ASSOCIATED WITH BASIC ROCK BEDS

1. Bashaw (p)
2. McAlpin (mw-sp)
3. Waldo (vp)

B. ASSOCIATED WITH SEDIMENTARY ROCK BEDS

1. Chehalem (mw-sp)
2. Cove (p)
3. Dupee (mw-sp)
4. Hazelair (mw-sp)
5. Helmick (sp)
6. Panther (p)
7. Suver (sp)

C. ASSOCIATED WITH LOESSIAL DEPOSITS

1. Cascade (sp)
2. Cornelius (mw)
3. Delena (p)
4. Goble (mw)
5. Kinton (mw)

II. UPLAND TERRACE TRANSITIONAL ZONE SOILS

1. Bornstedt (mw)
2. Carlton (mw)
3. Cottrell (mw)
4. Grande Ronde (p)
5. Hazelair (mw-sp)
6. Noti (p)
7. Pengra (sp)
8. Santiam (sp)
9. Santiam (mw)
10. Veneta (mw-sp)
11. Wollent (p)

III. TERRACE SOILS

A. ASSOCIATED WITH WILLAMETTE SILTS

1. Aloha (sp)
2. Amity (sp)
3. Awbrig (p)
4. Bashaw (p)
5. Coburg (mw)
6. Concord (p)
7. Conser (p)
8. Dayton (p)
9. Helvetia (w-mw)
10. Holcomb (sp)
11. Huberly (p)
12. Powell (sp)
13. Quatama (mw)
14. Woodburn (mw)

B. ADJACENT TO BROAD VALLEY FLOOD PLAIN

1. Clackamas (sp)
2. Courtney (p)
3. Natory (p)

IV. BROAD VALLEY FLOOD PLAIN SOILS

1. Cove (p)
2. Labish (p)
3. Mcbee (mw)
4. Moag (vp)
5. Rafton (vp)
6. Sauvie (p)
7. Semiahmoo (vp)
8. Verboort (p)
9. Wapato (sp)

ALPHABETICAL SOILS INDEX

SOIL NAME	DRAINAGE CLASS	PAGE
Santiam	(sp)	100
Santiam	(mw)	101
Sauvie	(p)	140
Semiahmoo	(vp)	141
Suver	(sp)	79
Veneta	(mw-sp)	102
Verboort	(p)	142
Waldo	(vp)	69
Wapato	(sp)	143
Wollent	(p)	103
Woodburn	(mw)	122

Key to Drainage Classes:

(w)	Well drained
(mw)	Moderately well drained
(sp)	Somewhat poorly drained
(p)	Poorly drained
(vp)	Very poorly drained

I. UPLAND SOILS

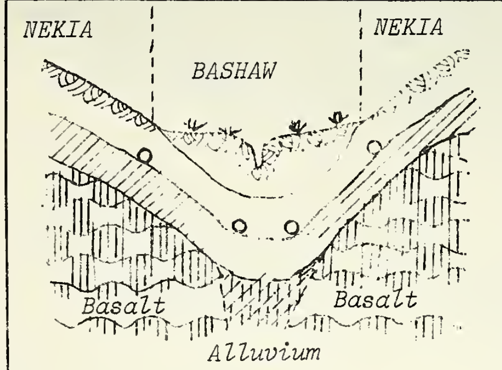
A. ASSOCIATED WITH BASIC ROCK BEDS

1. Bashaw (p)

2. McAlpin (mw-sp)

3. Waldo (vp)

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 100 - 1200'   AREA - 10 ac. or less   SLOPE - 3 - 12%

1. Poorly drained, deep black clay over dark gray clay.
2. Occurs on alluvial fans and along drainageways in small, narrow valleys.
3. Usually associated with Wapato, Dixonville, and Nekia.
4. Water movement is restricted by the very fine-textured profile.
5. Uniformly slow permeability through surface soil and subsoil to 40" to 50". Very slow permeability in substrata of alluvium below 40" to 50".

DRAINAGE PROBLEMS AND CONSIDERATIONS

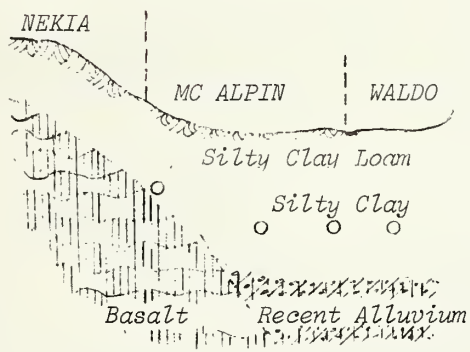
Surface drainage is recommended.
Interception will benefit this soil in most locations.
This soil has significant structure and tubular pores to depths of 3 1/2 feet thus closed drainage at moderate depths on close spacing may be effective.
Relief drainage may be necessary where soil occurs in narrow valleys.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Surface Drainage							
Field Ditches			70 to 90' x 700'			1 1/2	3.5
Land smoothing			Remove adverse slopes and field depressions				
Subsurface Drainage							
Interception drain (open or closed)			At contact with higher soil bodies	3 to 5'	Ia or IIa & IIIb	1 1/2	3.5
Closed pattern drainage			40 to 60'	3 to 4'	IIa & IIIc		

I-A-1

MC ALPIN

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 250' to 1000' AREA - 5-15 ac. SLOPE - 0 to 7%

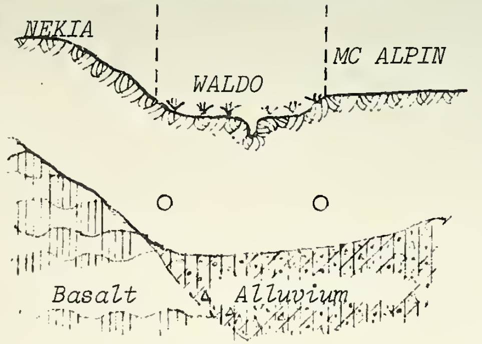
1. Very deep, moderately well to somewhat poorly drained, reddish brown silty clay loam over mottled silty clay.
2. Occurs on alluvial fans and higher bottomlands.
3. Associated with the well drained Nekia and Abiqua and the poorly drained Waldo.
4. The restriction is the finer textured "B" horizon that impedes and slows the movement of water downward and laterally.
5. Slow permeability in silty clay subsoil below 18" to 30". Moderately slow permeability in substrata of recent alluvial sediments below 50" to 60" or more.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception recommended when adjacent to Nekia.
Pattern drainage will reduce wetness due to restricted permeability of "B" horizon.
Surface is undulating and surface drainage will benefit wetter areas of runoff accumulation.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN	
						Z	MAX. VEL (f.p.s.)
<u>Subsurface Drainage</u>							
Interception drain (open or closed)			At upper edge of seepage area	3.5 to 5'	Ia or IIa & IIIc	1 1/2	3.0
Closed pattern drainage			50 to 70'	3 to 4'	IIa or IIIa & IIIc		
<u>Surface Drainage</u>							
Field ditches			400' maximum spacing			1 1/2	3.0
Land smoothing			Remove adverse slopes and field depressions				

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 250' to 1000' AREA - 5 ac. or less SLOPE - 0 to 3%

1. Very poorly drained, very deep, mottled dark reddish brown silty clay loam over mottled silty clay or clay.
2. Occurs on alluvial bottoms along small creeks and intermittent drainageways.
3. Usually associated with McAlpin on both sides.
4. Water movement is restricted by the very fine-textured profile.
5. Slow permeability in clay subsoil below. Moderately slow permeability in substrata of alluvial sediments below.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Surface drainage is recommended.
Interception drainage is feasible adjacent to upland soils.
Restricted internal drainage will require close spacing for crops requiring a pattern drainage system.
Porous backfill for closed drainage is important.
Relief drainage may be necessary as soil occurs along drainageways.

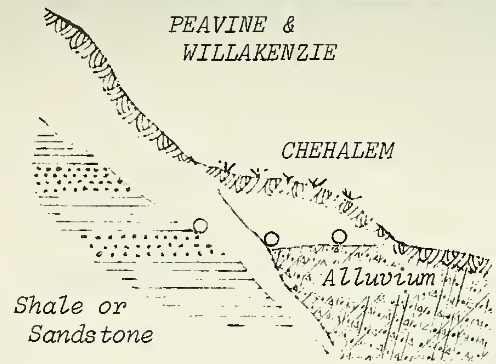
APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Surface Drainage							
Field ditches			200' maximum spacing			2	3.5
Land smoothing			Remove adverse slopes and field depressions				
Land grading			Slope to natural outlets				
Bedding			60 - 80' by 200'				
Subsurface Drainage							
Interception drain (open or closed)			At contact with higher soil bodies	3 to 5'	Ia or IIIa & IIIc	2	3.5
Closed pattern drainage			40 to 60'	3.5 to 4.5'	Ia or IIIa & IIIc		

I. UPLAND SOILS

B. ASSOCIATED WITH SEDIMENTARY ROCK BEDS

1. Chehalem (mw-sp)
2. Cove (p)
3. Dupee (mw-sp)
4. Hazelair (mw-sp)
5. Helmick (sp)
6. Panther (p)
7. Suver (sp)

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 160' AREA - 5-15 ac. SLOPE -

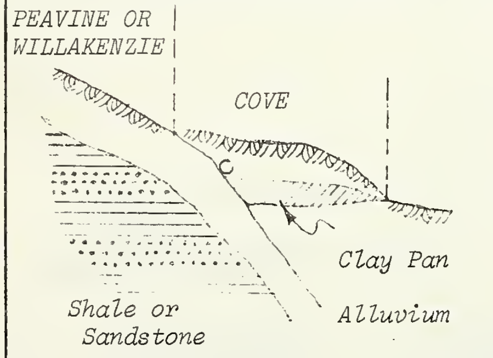
1. Moderately well to somewhat poorly drained, very deep, dark brown silty clay loam over somewhat mottled gray brown silty clay.
2. Occurs on fans, from uplands along secondary drainageways on gentle to moderate slopes.
3. Associated with Peavine, Bellfountain, Melby, Steiwer and Willakenzie soils on the uplands and with Cove soils on fans.
4. Wetness is due to water contributed by adjacent soils moderately shallow to moderately deep over shale bedrock.
5. Moderately slow permeability in silty clay subsoil below 20" to 36". Very slow permeability in substrata below 60" or more.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception drainage is recommended. Pattern drainage will prevent wetness due to impaired internal drainage. Depth of interception should be at or near bedrock.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX.VEL (f.p.s.)
Subsurface Drainage							
Interception drains (open or closed)			At contact with higher soil bodies	3 to 5'	Ia or IIIa & IIIc	1 1/2	3.5
Closed pattern drainage			40 to 50'	3.5 to 4.5'	IIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 200' AREA - 10 ac. or less SLOPE -

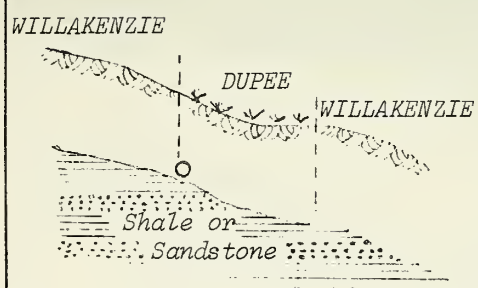
1. Poorly drained, deep, very dark gray-brown silty clay loam over mottled clay.
2. Occurs on convex slopes along upland drainageways.
3. Associated with Steiwer, Willakenzie, Peavine, and Melby.
4. Very slowly permeable strata.
5. Moderately slow permeability in silty clay surface soil. Slow permeability in clay subsoil below 5" to 10". Very slowly permeable substrata below 40" to 60".

DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception drains are recommended.
Depth of interception should be at or near the impervious substrata. Pervious filter and backfill are important for tile drainage.
Surface drainage is recommended only where the natural surface drainage of this soil is impaired.
Intensity of surface drainage dependent upon land use and cropping.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Subsurface Drainage							
Interception drain (open or closed)			At upper edge of the seepage area	3.0 to 4.5'	Ia or IIIa & IIIc	2	5.0
Surface Drainage							
Land smoothing			Remove adverse slopes and field depressions				

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 250'   AREA - 10 ac. or less   SLOPE -

1. Moderately well to somewhat poorly drained, deep, dark brown silt loam over mottled, moderately slowly permeable silty clay loam resting on shattered sandstone or shale.
2. Occurs in depressions and along upland drainageways.
3. Associated with well-drained Willakenzie, Peavine, Bellfountain, or Steiwer soils on adjacent uplands.
4. Wetness is due to seepage moving down adjacent slopes on top of shale and sandstone.
5. Moderately slow permeability in silty clay subsoil below 19" to 30". Very slow permeability in substrata below 48" to 60" or more.

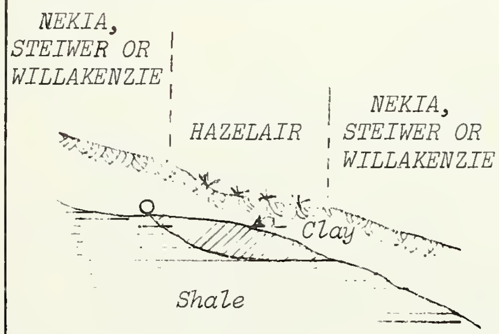
DRAINAGE PROBLEMS AND CONSIDERATIONS

Relief drainage or improvement of drainageways is recommended as soil occurs in narrow swales. Depth of drains should be as close to substrata as possible for best results.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Subsurface Drainage							
Relief drain (open or closed)			In center of depression	3.0 to 5.0'	IIa & IIIc	1 1/2	3.5
Closed interception drain			At upper edge of seepage area	3.0 to 5.0'	Ia or IIa & IIIc		

I-B-3

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 300' AREA - 5-15 ac. SLOPE -

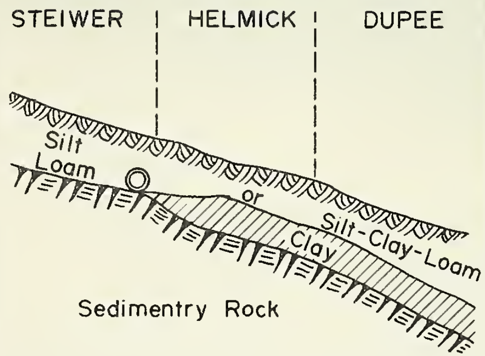
1. Moderately well or somewhat poorly drained, very dark brown silty clay loam, shallow to moderately deep to clay over shale.
2. Concave side and footslopes.
3. Occurs within bodies of Peavine, Willakenzie, or Steiwer.
4. Finer texture of Hazelair creates a block to water moving along shale, causing wet areas.
5. Slow permeability in clay subsoil below 24" to 34". Very slow permeability in substrata below 35 to 60 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Frequently occurs in extensive narrow areas running across the slope.
Interception drainage is recommended.
Tile lines will normally extend into the clay subsoil.
Porous backfill should extend above clay subsoil.
Random tile lines will apply in small, wet areas (usually inclusions in associated soils).

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX.VEL (f.p.s.)
Subsurface Drainage							
Closed interception drain			At upper edge of seepage area	3.0 to 4.0'	Ia or IIa & IIIc		
Open interception drain			At upper edge of seepage area	3.0 to 5.0'		1 1/2	3.5
Closed random drainage			In depressional wet areas	3.0 to 4.0'	IIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION: 250-400 AREA: SLOPE: 3-20%

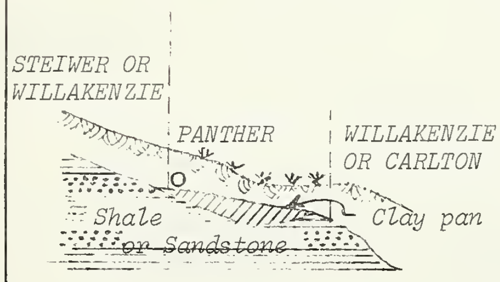
1. Somewhat poorly drained, very deep soil formed in mixed alluvium and colluvium over residuum weathered from sandstone and siltstone. The surface layer is silt loam and silty clay loam about 10 inches thick. The subsoil is silty clay loam about 6 inches thick. The substratum is mottled and very plastic clay about 46 inches or more thick. The depth to bedrock is greater than 60 inches.
2. Occurs on low rolling foothills.
3. Associated with Dupee, Santiam, Steiwer, Suver and Willakenzie soils.
4. Finer texture of Helmick creates a block to water moving along sandstone or siltstone.
5. Slow permeability in subsoil and very slow permeability in the substratum.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception drainage is recommended.
Closed drains should normally extend into the clay subsoil.
Porous backfill should extend above clay subsoil.
Random closed drain lines may be used in small wet areas.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL
Subsurface Drainage							
Closed interceptor drain			At upper edge of seepage area.	3 to 4'	Ia or IIa & IIIc		
Open interceptor drain			At upper edge of seepage area.	3 to 5'		1½	3.5
Closed random drainage			In depressional wet areas	3 to 4'	IIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 160 to 600' AREA - 5 ac. or less SLOPE -

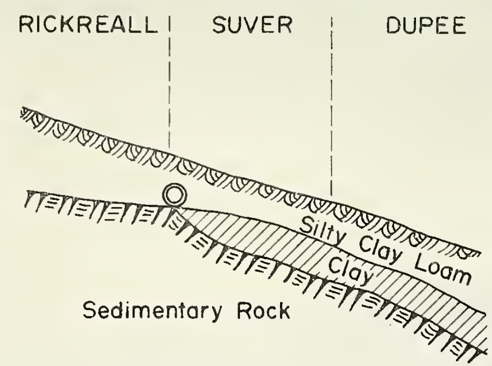
1. Poorly drained, shallow, very dark gray-brown silty clay loam over olive gray clay resting on fractured shale bedrock at less than 60".
2. Occurs on gentle to moderate slopes on upland fans and in depressions along drainageways.
3. Associated with Willakenzie, Peavine, Melby, or Steiwer.
4. Wetness is due to seepage moving down adjacent slopes on top of shale and sandstone.
5. Slow permeability in clay subsoil below 8" to 12". Very slow permeability in substrata below 48" to 60".

DRAINAGE PROBLEMS AND CONSIDERATIONS

Surface drainage and interception are both recommended.
Depth of interception should approach shale or sandstone.
Pervious filter and backfill are important for closed drainage.
Closed random drains will be effective in swale formations and depressions.
This soil is normally found in depressions.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX.VEL (f.p.s.)
Surface Drainage							
Field ditches			400' maximum spacing			1½	4.0
Land smoothing			Remove adverse slopes and field depressions				
Subsurface Drainage							
Closed interception drain			At upper edge of seepage area	3.0 to 4.0'	Ia or IIa & IIIc		
Closed random drains			Through the depression	3.0 to 4.0'	IIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION: 275-800' AREA: SLOPE: 3-20%

1. Somewhat poorly drained soils formed in fine textured colluvium and residuum from sedimentary bedrock. The surface layer is silty clay loam about 11 inches thick. The subsoil is mottled heavy silty clay and clay about 17 inches thick. The substratum is clay. Depth to bedrock ranges from 40 to 60 inches.
2. Occur on gentle smooth ridges and on steep foothills.
3. Associated with Bellpine, Dupee, Jory, Rickreall, and Willakenzie soils.
4. Wetness is due to seepage moving down adjacent slopes being blocked by the finer textured Suver soil.
5. Permeability is very slow below 11 inches in depth.

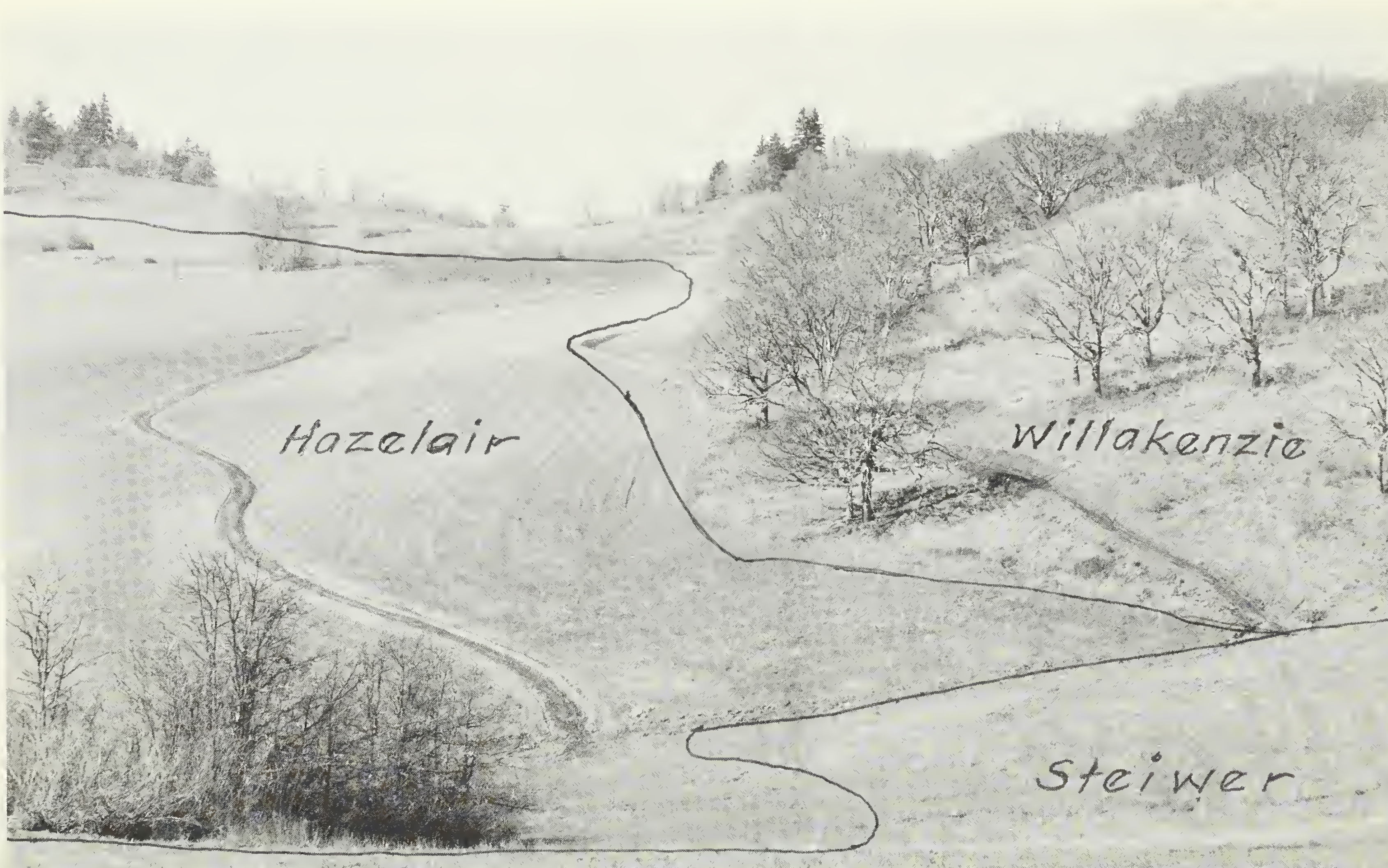
DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception drainage is recommended.
Closed drains should normally extend into the subsoil.
Porous backfill should extend above the subsoil.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN	
						Z	MAX. VEL
Subsurface Drainage							
Closed interceptor drain			At upper edge of seepage area.	3 to 4'	Ia or IIa & IIIc		
Open interceptor drain			At upper edge of seepage area.	3 to 5'		1½	3.5
Closed random drainage			In wet areas.	3 to 4'	IIa or IIIc		

I-B-7

Yamhill - Panther - Willakenzie association. (Photo 0-613-7)



Willakenzie - Hazelair - Steiwer landscape. (*Photo No. Ore-45107*)

I. UPLAND SOILS

C. ASSOCIATED WITH LOESSIAL DEPOSITS

1. Cascade (sp)

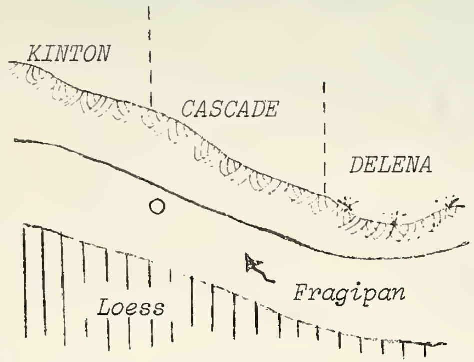
2. Cornelius (mw)

3. Delena (p)

4. Goble (mw)

5. Kinton (mw)

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 100-1400'   AREA - 10-over 40 ac.   SLOPE - 3-20%

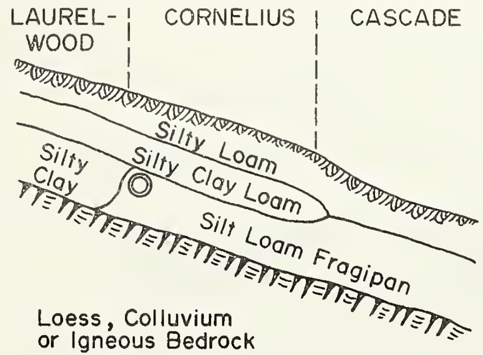
1. Somewhat poorly drained, very deep soil with dark brown silt loam over variegated mottled and strongly compacted silt loam or silty clay loam.
2. Occurs on lower side hills and footslopes on uplands.
3. Associated with Laurelwood, Kinton and Delena.
4. Wetness is due to restriction of permeability in compacted layers. Water contributed from higher lying areas aggravates wetness problem.
5. Slow permeability in fragipan layers in subsoil below 20 to 30 inches. Moderately slow permeability in substrata of loess below 60 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception drainage is recommended where land form is suitable.
Random tile drainage may be effective for wetter areas.
Pattern drainage will be feasible where slopes permit.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX.VEL (f.p.s.)
<u>Subsurface Drainage</u>							
Interception drainage (open or closed)			At upper edge of seepage area	4 to 5'	Ia or IIa & IIIc	1 1/2	3.0
Closed random drainage			In depressional wet areas	3 to 5'	IIa & IIIc		
Closed pattern drainage			40 to 50'	3.5 to 4.5'	IIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION: 350-800' AREA: 5-160 Acres SLOPE: 2-20%

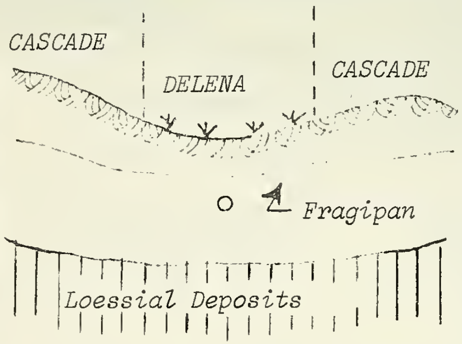
1. Moderately well drained, deep soil with dark brown silt loam over a dark brown silty clay loam. It is underlain by a firm to very firm silt loam fragipan commonly over 2 feet thick.
2. Occurs on gently sloping to rolling low hills and steep hillslopes. An upland soil.
3. Associated with Cascade, Helvetia, Saum, Kinton and Laurelwood soils.
4. Wetness due to subsurface water contributed from higher lying areas.
5. Moderate permeability in the top 38 inches. Slow permeability in the fragipan layer below 38 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception drainage is recommended where slope is not too great.
Random drains may be effective for wetter areas if slope is not excessive.
Pattern drains may be helpful for erosion control as well as drainage. Steeper slopes require closer spacing.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL
Subsurface Drainage							
Closed random drainage			In depressional wet areas	3 to 5'	IIIa, IIIc		
Closed interception drainage			At upper edge of seepage	4 to 5'	IIIa, IIIc		
Closed pattern drainage			40-60' (on steep slopes)	3 to 5'	IIIa, IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 100-1400' AREA - 5 ac. or less SLOPE - 3-12%

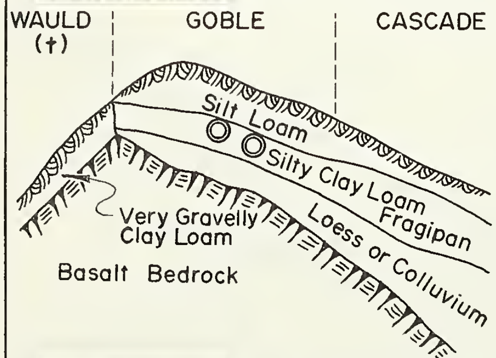
1. Poorly drained, very deep soil with very dark gray silt loam over gray brown highly mottled silty clay loam with moderately compacted layers.
2. Occurs on concave slopes in slumps and depressions on uplands.
3. Associated with Laurelwood, Kinton, Cascade and Helvetia.
4. Position and compacted layers in subsoil as well as lack of well developed drainageways contribute most to wetness problem.
5. Slow permeability in fragipan layers in subsoil below 20 inches. Moderately slow permeability in substrata of loess below 60 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Drainage problem due to concentration of water moving on the fragipan into low swales and pockets.
Random tile drainage is recommended to relieve wet pockets and small areas of runoff accumulation.
Porous backfill is important.
Field drains may be installed to provide outlet to drainageway to relieve ponding.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Surface Drainage							
Field ditches			70' to 90' x 700'			2	3.0
Subsurface Drainage							
Closed random drainage			In depressional wet areas	3.5 to 5'	IIa & IIIc		
Closed pattern drainage			40 to 50'	3.5 to 5'	IIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION: 400-1800' AREA: 5-100 Acres SLOPE: 2-20%

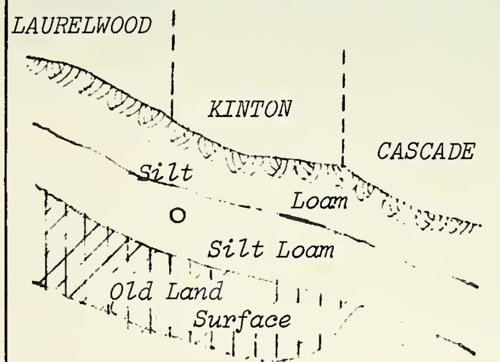
1. Moderately well drained deep soil with very dark grayish silt loam and dark brown silt loam and silty clay loam underlain by a very firm fragipan 2 or more feet thick.
2. Occurs on smooth or rolling hills with convex, long slopes and ridgetops.
3. Associated with Delena, Olyic, Melby and Cascade.
4. Wetness is due to a perched water table over the fragipan.
5. Moderate permeability in the top 37 inches and slow permeability in the fragipan (below 37 inches).

DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception drainage is recommended where landform is suitable.
Random tile drainage may be effective for wetter areas if slope is not excessive.
Pattern drains are helpful for erosion control as well as drainage. Steeper slopes require closer spacing.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX.VEL
Subsurface Drainage							
Closed random drainage			In depressional wet areas	3 to 5'	IIIa, IIIc		
Closed interception drainage			At upper edge of seepage	4 to 5'	IIIa, IIIc		
Closed pattern drains			40-60' (on steep slopes)	3 to 5'	IIIa, IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 250-800'   AREA - 5-over 40 ac.   SLOPE - 2-20%

1. Moderately well drained, very deep soil with dark brown silt loam over dark yellowish brown silt loam with slightly compacted layers.
2. Occurs in convex positions on side slopes and along field drainageways on uplands.
3. Associated with well drained Laurelwood and somewhat poorly drained Cascade soils.
4. Wetness is due to subsurface water contributed from higher lying areas.
5. Moderately slow permeability in lower subsoil below 30 to 40 inches. Slow permeability in silty clay old land surface substrata below 60 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

The slope of this soil may limit the use of interception drainage.
Random tile will be possible in wet areas if slope is not excessive.

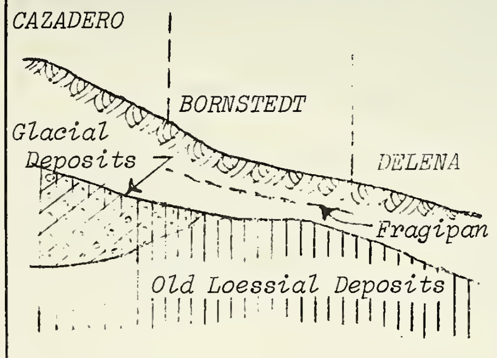
APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Subsurface Drainage							
Closed random drainage			In depressional wet areas	3 to 5'	IIIa		
Closed interception drainage			At upper edge of seepage	4 to 5'	IIIa		
Closed pattern drains			55 to 65'	3 to 5'	IIIa		

I-C-5

II. UPLAND TERRACE TRANSITIONAL ZONE SOILS

1. Bornstedt (mw)
2. Carlton (mw)
3. Cottrell (mw)
4. Grande Ronde (p)
5. Hazelair (mw-sp)
6. Noti (p)
7. Pengra (sp)
8. Santiam (sp)
9. Santiam (mw)
10. Veneta (mw-sp)
11. Wollent (p)

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 600' AREA - 15-25 ac. SLOPE - 3-20%

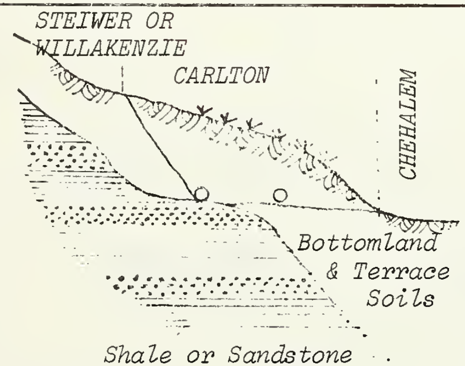
1. Moderately well drained, deep soil with dark brown silt loam over dark brown silty clay loam that rests on old loessial deposits with strongly compacted layers.
2. Occurs on lower side slopes and in depressions of undulating uplands.
3. Associated with Cazadero and Delena on uplands and occasionally adjacent to Powell soils on the terrace.
4. Wetness due to position with contributions of water from higher lying areas and to restricted permeability of compacted layers in substrata.
5. Moderately slow permeability in subsoil below 12 to 24 inches. Slow permeability in substrata of old loessial deposits below 36 to 48 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception drainage is recommended.
Pattern drainage will reduce wetness due to restricted permeability of compacted layers.
Porous backfill should extend above the fragipan for tile systems.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Subsurface Drainage							
Interception drainage (open or closed)			At upper edge of seepage area	3.5 to 5'	Ia or IIa & IIIc	1 1/2	3.5
Closed pattern drainage			50 to 70'	3 to 4'	IIa & IIIc		
Closed random drainage			In depressional wet areas	3 to 4.5'	IIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 150' to 400' AREA - 10-over 40 ac. SLOPE - 0-20%

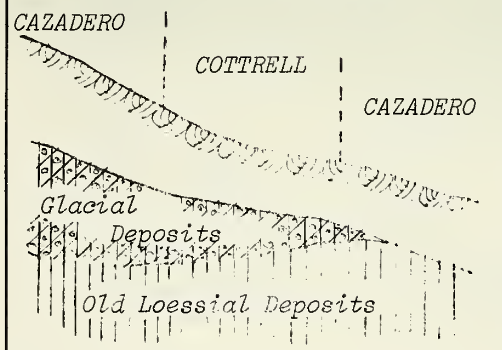
1. Moderately well-drained, very deep, dark brown silt loam over slightly mottled clay loam.
2. Occurs on gentle and moderate slopes on broad, silty terraces adjacent to soils on sedimentary uplands.
3. Associated with well-drained Steiwer and Willakenzie soils.
4. Wetness is due to seepage moving down adjacent slopes on top of shale and sandstone.
5. Moderate permeability in silty clay loam subsoil below 20" to 30". Moderate permeability in substrata of mixed alluvial deposits below 60" or more.

DRAINAGE PROBLEMS AND CONSIDERATIONS

This moderately well drained soil responds well to drainage.
Improved drainage is recommended for those crops requiring good drainage.
Interception drainage is recommended.
Closed pattern drainage will prevent wetness when caused by impervious substrata.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN	
						Z	MAX.VEL (f.p.s.)
Subsurface Drainage							
Interception drains (open or closed)			At upper edge of seepage area	3 to 5'	IIa & IIIc	2	3.5
Closed pattern drainage			55 to 65'	3.5 to 4.5'	IIIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 820' AREA - 10-20 ac. SLOPE - 3 to 7%

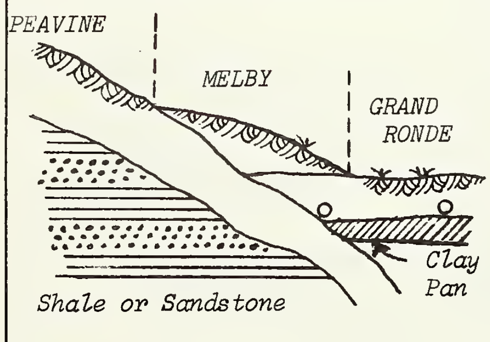
1. Moderately well drained, very deep soil with very dark brown silt loam over dark brown silty clay that is mottled in the lower part.
2. Occurs on lower side slopes and in depression of undulating uplands.
3. Associated with well drained Cazadero soils.
4. Wetness due to contribution of subsurface water from adjacent, higher lying areas.
5. Moderately slow permeability in subsoil below 24 to 32 inches. Moderately permeable substrata of glacial deposits below 60 to 70 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception drainage is recommended.
Pattern or random drainage, depending on the severity of undulations, will reduce wetness due to moderately slow permeability of the subsoil.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Subsurface Drainage							
Interception drainage (open or closed)			At upper edge of seepage area	3.5 to 4.5'	IIa & IIIc	1 1/2	3.5
Closed pattern drainage			60 to 80'	3 to 4'	IIa & IIIc		
Closed random drainage			In depressional wet areas	3 to 4.5'	IIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 300'-500' AREA - 10 ac. or less SLOPE - 0-3%

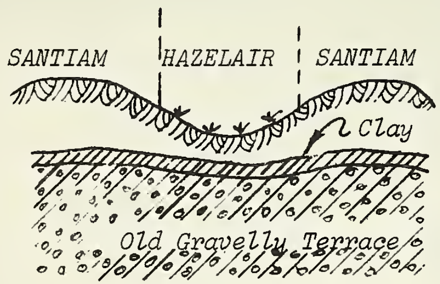
1. Poorly drained, moderately deep, mottled very dark brown silty clay loam over clay pan at 18" - 36" over shale bedrock within 60".
2. Occurs in depressional areas at the base of fans or terraces on level to gentle slopes.
3. Associated with Peavine and Melby.
4. Downward movement of water is stoped by clay pan.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Both surface and subsurface drainage practices are recommended.
The intensity of surface drainage will be dependent upon land use and slope.
Pattern drainage is recommended for use in conjunction with systems on adjacent soils and on the deeper phases of this soil.
Depth of interception should be at or in the clay pan.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Surface Drainage							
Field ditches			300' maximum spacing			2	3.5
Land smoothing			Remove adverse slopes				
Land grading			Slope to natural outlets				
Bedding			70 to 90' by 700'				
Subsurface Drainage							
Interception drain (open or closed)			At contact with higher soil bodies	3.5 to 4.0'	Ia or IIa & IIIc	2	3.5
Closed pattern drainage			50' by 70'	3.0 to 4.0'	IIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION 300 to 400' AREA - 5 ac. or less SLOPE - 0-3%

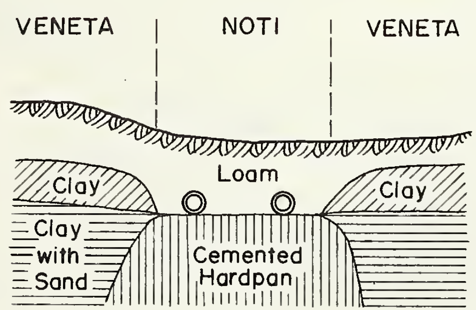
1. Moderately well to somewhat poorly drained, mottled grayish brown silty clay loam over mottled gray-brown clay resting on compacted gravels in weathered bedrock.
2. Occurs in depressional areas and along drainageways on the terrace.
3. Associated with Santiam and Nekia.
4. Downward movement of water is restricted by clay subsoil and compaction in gravelly substrata.
5. Very slow permeability in clay subsoil below 24 to 32 inches. Very slow permeability in substrata of old gravelly alluvium or weathered bedrock below 50 to 60 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Surface of this soil can be flat and it normally occurs in narrow depresssional areas. Surface methods will improve drainage by speeding runoff and reducing ponding. Closed subsurface drains are not feasible.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Surface Drainage							
Field ditches			300' maximum spacing			2	4.0
Bedding or			70 to 90' x 700'				
Land smoothing			Remove adverse slopes and field depressions				
Subsurface Drainage							
Open random drain			In drainageway or center of wet depressional area	3 to 5'		2	4.0

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION: 300' - 800' AREA: 1 - 100 acres SLOPE: 0-3%

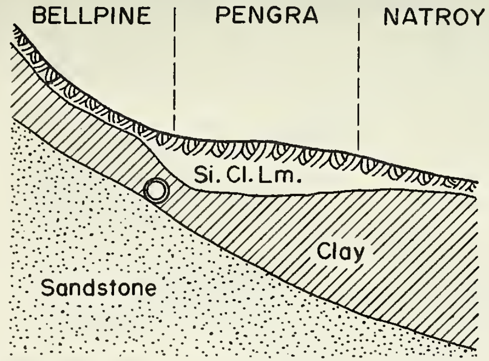
1. Moderately deep, poorly drained soil formed in alluvium from weathered sandstone and terrace materials. The surface layer is loam about 9 inches thick. The subsoil is loam or sandy loam about 25 inches thick. The substratum is weakly cemented very gravelly loamy sand. Depth to cemented hardpan is 30 to 40 inches.
2. Occupies nearly level bottoms and flood plains of drainageways dissecting old terraces.
3. Associated with Dayton, Holcomb, Linslaw, Natroy, Salkum, and Veneta soils.
4. Downward movement of water is restricted by the cemented hardpan.
5. Moderately rapid permeability in the subsoil. Slow permeability in the cemented hardpan.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Closed subsurface drainage is recommended.
Depth of closed drains should be at or in the cemented hardpan.
Surface methods will improve drainage where runoff is slow.
Outlets are the most critical limitation in some areas.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN	
						Z	MAX.VEL
Subsurface Drainage							
Closed pattern drainage			80 to 100'	3 to 4'	IIa & IIIc		
Closed random drainage			In depressional wet areas	3 to 4'	IIa & IIIc		
Surface Drainage							
Field ditches			500' maximum spacing			1½	4.0
Land smoothing			Remove adverse slope and field depressions				

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION: 350' - 1000' AREA: 4-40 acres SLOPE: 1-3%

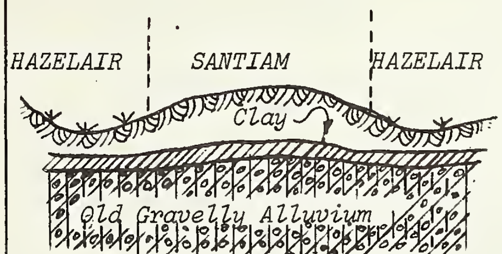
1. Somewhat poorly drained, silty clay loam over clay soil formed in clayey alluvium. The surface layer is silty clay loam about 21 inches thick. This is underlain by a clay that extends to depths greater than 40 inches.
2. Occupies very gently sloping toe slopes or alluvial fans of foothills.
3. Associated with Bellpine, Courtney, Hazelair, and Natroy soils.
4. Wetness is due to seepage moving down adjacent slopes on top of shale and sandstone.
5. Very slow permeability in the clay subsoil.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Surface drainage and interception are both recommended.
Depth of interception should approach shale or sandstone.
Pervious filter and backfill are important for closed drainage.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN	
						Z	MAX. VEL
Surface Drainage							
Field ditches			400' maximum spacing			1½	3.5
Land smoothing			Remove adverse slopes and field depressions.				
Subsurface Drainage							
Closed interception drain			At upper edge of seepage area.	3 to 4'	Ia or IIa & IIIc		
Closed random drains			Through the depression	3 to 4'	IIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

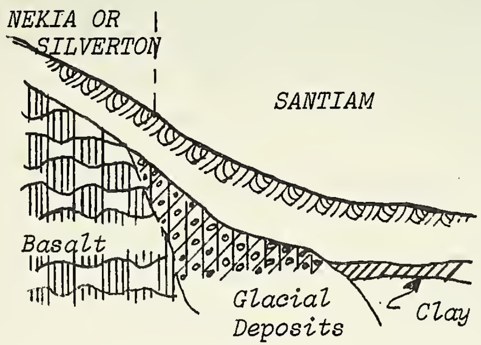
ELEVATION - 300 to 325'   AREA - 10-20 ac.   SLOPE 4-8%

1. Imperfectly drained, very deep, dark brown silt loam over mottled silty clay loam and silty clay over gravels.
2. Old gravelly terrace, the second one above the floodplain.
3. Associated with Silverton.
4. Clay layer restricts downward water movement and creates a perched water table.
5. Slow permeability in silty clay subsoil below 20" to 30". Slow permeability in substrata of old gravelly alluvium below 60" to 72".

DRAINAGE PROBLEMS AND CONSIDERATIONS

Surface undulations and depth limitation for closed drainage should be considered in planning a drainage system.
Interception drainage is recommended when adjacent to Silverton and land form permits.
Closed random drains will be effective.
Pattern drainage should be considered on flatter phases of this soil.
Porous backfill or closed systems should extend above the silty clay subsoil.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Subsurface Drainage							
Interception drainage (open or closed)			At contact with higher soil bodies	3 to 5'	Ia or IIa & IIIc	1 1/2	3.5
Closed random drainage			In depressional wet areas	3 to 5'	Ia or IIa & IIIc		
Closed pattern drainage			50 to 70'	3 to 4.5'	Ia or IIa & IIIc		

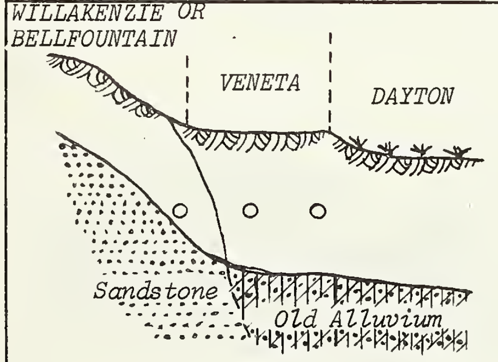
SOIL ASSOCIATION SKETCH	PHYSICAL FACTORS IN SOIL PROFILE
	ELEVATION - 325 to 375' AREA - 5 ac. or less SLOPE - 3-35% 1. Moderately well-drained, deep soil with dark brown clay loam over variegated and mottled clay resting on slightly compacted very gravelly silty clay loam. 2. Occurs on lower slope positions on gently undulating gravelly terraces that border the uplands. 3. Assicated with Silverton and Hazelair and Amity or Woodburn on the terrace. 4. Wetness due to restriction in permeability of the clay subsoil and to excess water contributed by higher lying areas. 5. Slow permeability in clay subsoil below 18" to 24"; slow permeability in substrata of old gravelly alluvium or weathered bedrock below 40" to 60".

DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception drainage is recommended where land form is suitable.
Closed random drains will be effective in swale formations and depressions when slope permits.
Porous backfill should extend above the clay subsoil.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Subsurface Drainage							
Interception drainage (open or closed)			At upper edge of seepage area	3 to 5'	Ia or IIa & IIIa	1 1/2	4.0
Closed random drains			In center of depression	3 to 5'	IIa & IIIa		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

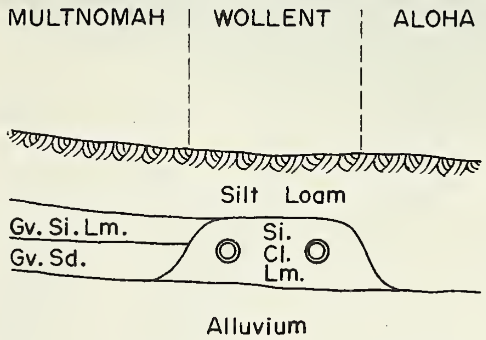
ELEVATION - 350' to 500'   AREA - 5-15 ac.   SLOPE - 0-12%

1. Moderately well to imperfectly drained, deep, dark grayish brown loam over clay loam subsoil that is moderately compacted, in strata, below 46".
2. Occurs in small bodies on alluvial terraces adjacent to upland soils formed in sedimentary residuum.
3. Adjacent to uplands of Willakenzie and Bellfountain soils and terraces of Dayton soils.
4. Wetness is due to position with water contributed by runoff from adjacent uplands during periods of excessive rainfall.
5. Moderately slow permeability in clay loam subsoil below 10" to 24". Slow permeability in substrata below 40" to 60" or more.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception drainage is recommended.
Pattern drains will benefit wetter phases of this soil or may be used for more intense cropping systems.

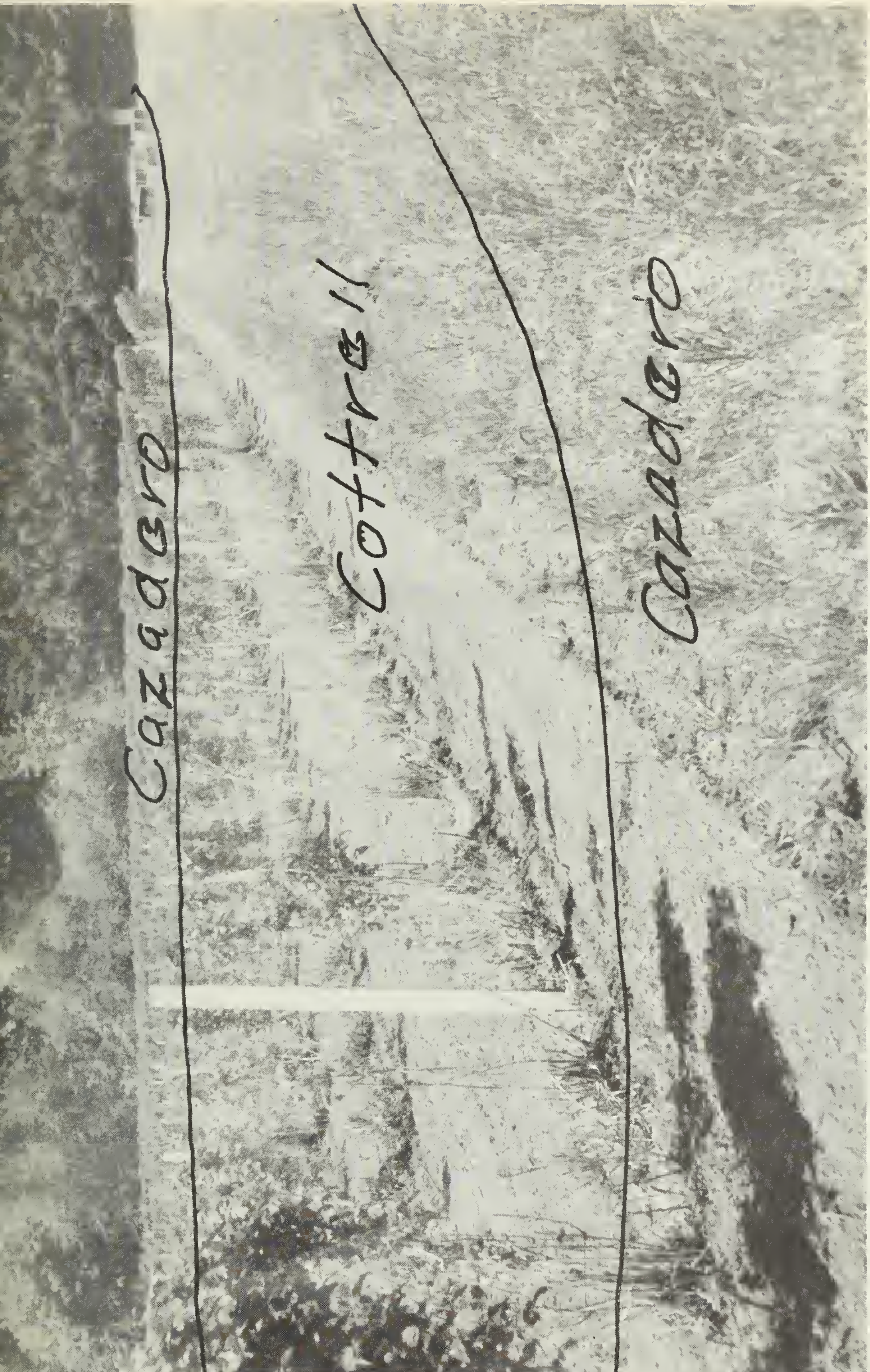
APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX, VEL (f.p.s.)
Subsurface Drainage							
Interception drain (open or closed)			At upper edge of seepage area	3.5 to 5'	IIa & IIIc	2	3.0
Closed pattern drainage			60 to 80'	3.5 to 4.5'	IIIa & IIIc		
Surface Drainage							
Land smoothing			Remove adverse slopes and field depressions				

SOIL ASSOCIATION SKETCH	PHYSICAL FACTORS IN SOIL PROFILE
	ELEVATION: 200-400' AREA: 5-100 acres SLOPE: 0-3% 1. Poorly drained, very deep soils that formed in old, silty alluvium. The surface layer is silt loam about 9 inches thick. The subsoil is slightly mottled silt loam about 15 inches thick. The substratum is mottled silty clay loam over 3 feet thick. 2. Occurs on high terraces. 3. Associated with Aloha, Latourell, Multnomah, and Powell soils. 4. Downward movement of water is restricted by the fine textured substratum. 5. The permeability of the substratum is moderately slow.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Surface has slow runoff.
Has a seasonally perched water table at or within 10 inches of the surface.
Both surface and subsurface drainage are recommended.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL
Surface Drainage							
Field ditches Land grading Bedding			300' maximum spacing Slope to natural outlet 70 to 90' by 700'			1½	3.5
Subsurface Drainage							
Random drains (open or closed)			In depressions	3 to 5'	IIa & IIIc	1½	3.5
Closed pattern drainage			40 to 60'	3.5 to 4.5'	IIa & IIIc		



Cazadero-Cottrell Soil Association (Photo No. 0-2855-16)

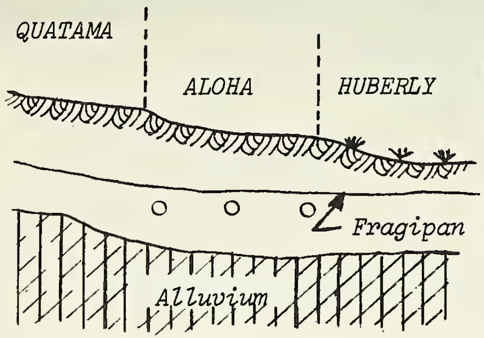
Carlton soil associated with Willakenzie and Chehalem soils.
(Photo No. 0-606-11)

III. TERRACE SOILS

A. ASSOCIATED WITH WILLAMETTE SILTS

1. Aloha (sp)
2. Amity (sp)
3. Awbrig (p)
4. Bashaw (p)
5. Coburg (mw)
6. Concord (p)
7. Conser (p)
8. Dayton (p)
9. Helvetia (w-mw)
10. Holcomb (sp)
11. Huberly (p)
12. Powell (sp)
13. Quatama (mw)
14. Woodburn (mw)

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 150'-200'   AREA - 10-over 40 ac.   SLOPE - 0-3%

1. Somewhat poorly drained very deep soil with dark brown silt loam over dark yellowish brown, mottled, silt loam subsoil with moderately compacted layers.
2. Occurs on gently sloping terraces ajdacent to uplands.
3. Associated with Woodburn, Quatama and Huber.
4. Wetness due to restriction of permeability in compacted layers.
5. Slow permeability in weak fragipan layers in lower subsoil below 30 to 50 inches. Moderate permeability in substrata of very fine sandy and silty alluvium below 60 inches.

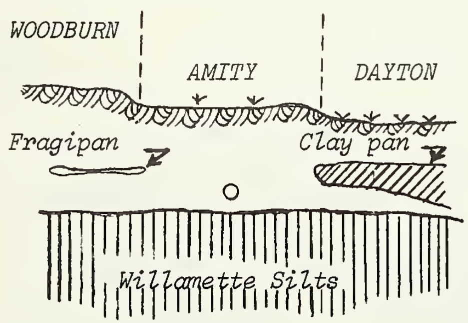
DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception and pattern drainage are recommended. The weak fragipan is the primary cause of wetness and porous backfill should extend above these compacted layers.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Subsurface Drainage							
Interception drainage (open or closed)			At upper edge of seepage area or field boundary	3.5 to 5'	Ia or IIa & IIIc	1 1/2	3.0
Closed pattern drainage			55 to 65'	3 to 4'	IIa & IIIc		

AMITY

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 150-400'   AREA - 20-over 40 ac.   SLOPE - 0-3%

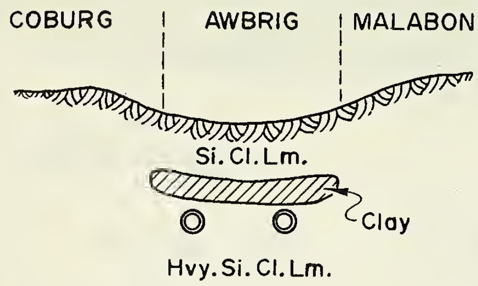
1. Somewhat poorly drained; very deep, very dark gray-brown silt loam over mottled dark gray-brown silty clay over Willamette silts.
2. Occurs on old alluvial terrace on level to gentle slopes.
3. Associated with Woodburn, Concord, Holcomb and Dayton.
4. Wetness is due to permanent water table that fluctuates with seasons of high rainfall.
5. Moderate permeability throughout soil.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Closed pattern drainage is recommended.
Random closed drainage will relieve wetness in depressional areas.
Surface drainage will relieve surface ponding and speed runoff.
Drainage of adjacent areas of Dayton will also facilitate drainage.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Subsurface Drainage							
Closed pattern drainage			40 to 50'	3.5 to 5'	IIIa & IIIc		
Closed random drainage			In depressional wet areas	3 to 4'	IIa & IIIc		
Surface Drainage							
Field ditches			400' maximum spacing			2	3.0
Land smoothing			Remove adverse slopes and depressional areas				

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 250' - 600'   AREA - 5 -- Over 150 acres   SLOPE - 0-2%

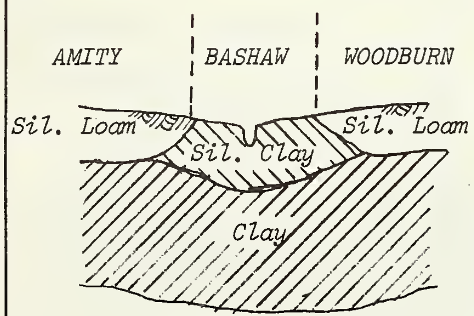
1. Poorly drained soils formed in clayey and silty alluvium.
2. Occurs on nearly level to slightly concave stream terraces and drainageways.
3. Associated with Coburg and Malabon.
4. Downward movement of water restricted by dense clay.
5. Permeability is very slow. Roots are restricted at 6 to 12 inches by the dense clay and winter water table.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Soil surface is subject to ponding.
Surface drainage will relieve ponding and speed runoff.
Tile should be placed below the clay layer.
Effectiveness of subsurface drainage is affected by the clay layer.
Filter placement and backfill are important.
Improvement of natural drainageways should be considered.
Suitable outlets for tile are hard to find in some areas.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN	
						Z	MAX.VEL
Surface Drainage							
Field ditches			300' maximum spacing			1½	3.0
Land grading			700' maximum length				
Bedding			70 to 90' by 700'				
Subsurface Drainage							
Closed pattern drainage			40 to 60'	3.5 to 5'	Ia or IIa & IIIa		
Relief drains			In natural drainageway or for outlet	3.5 to 5'		1 1/2	3.0

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

Elevation - 100 - 1200'   Area - 20-40 Acres   Slope: 0 -1%

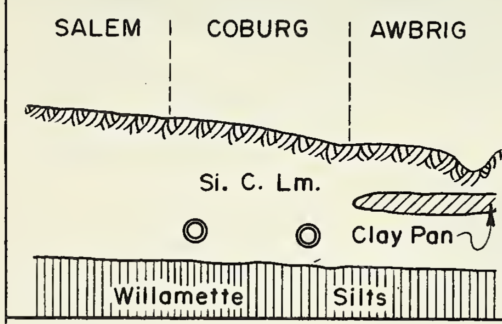
1. Poorly drained, deep soil with dark brown clay over dark gray massive clay.
2. Occurs in low areas on the terrace.
3. Associated with Dayton, Amity and foothill soils.
4. Water movement is restricted by the very fine textured profile.
5. Very slow permeability in substrata below 12 inches. Very slow permeability in substrata below 36 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Surface drainage is recommended on this flat, very poorly drained soil.
Tile drainage is not feasible on this soil.
Natural drainageways should be improved and open ditches may be necessary for outlet of surface drainage.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
<u>Surface Drainage</u>							
Field ditches			200' maximum spacing			2 1/2	3.0
Land grading			Slope to natural outlets				
Bedding			60 to 80' by 600'				
<u>Subsurface Drainage</u>							
Open relief drainage			Natural drainageways or as surface drainage outlet	3 to 4'		2 1/2	3.0

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION: 150 - 700' AREA: 5-100 acres SLOPE: 0-3%

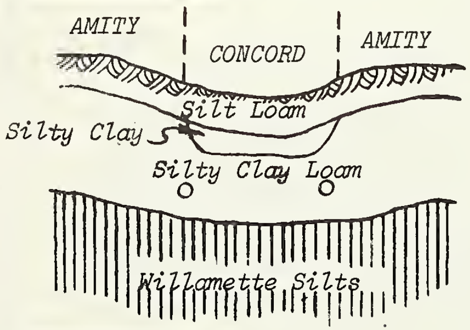
1. Moderately well drained,deep, silty clay loam over mottled silty clay loam at 18" - 53" over mottled silty clay loam to fine sandy loam to over 60".
2. Occupies nearly level low stream terraces on nearly level slopes.
3. Associated with Dayton, Conser, and Salem.
4. Wetness due to clayey texture and slow permeability of the subsoil.
5. Moderately slow permeability in the silty clay loam subsoil.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Closed subsurface drainage is recommended for optimum use of this soil.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL
Subsurface Drainage							
Closed pattern drainage			60 to 80'	3.5 to 5'	IIb & IIIc		
Closed random drainage			In depressional wet area	3.5 to 5'	IIb & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 150-400' AREA - 10-20 ac. SLOPE - 0-3%

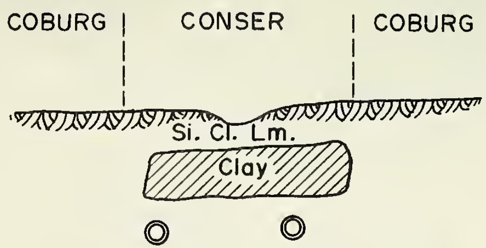
1. Poorly drained, very deep, mottled dark grayish brown silt loam over mottled silty clay loam.
2. Occurs in depressional areas or at heads of drainageways.
3. Associated with Amity above and at sides, and Dayton below.
4. Water movement is slightly restricted by the finer textured "B" horizon and the lack of good surface drainage.
5. Moderately slow permeability in silty clay subsoil below 24 to 32 inches. Moderate permeability in substrata of Willamette silts below 60 to 70 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Both surface and subsurface drainage are needed.
Pattern drainage will work well.
Random closed drains will relieve wetness in depressional and narrow areas.
Surface drainage will reduce ponding and speed runoff.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN	
						Z	MAX. VEL (f.p.s.)
Surface Drainage							
Field ditches			300' maximum spacing			1½	3.5
Land grading			Slope to natural outlet				
Bedding			70 to 90' by 700'				
Subsurface Drainage							
Random drains (open or closed)			In drainageway or center of depression	3 to 5'	IIa & IIIc	1½	3.5
Closed pattern drainage			60 to 80'	3.5 to 4.5'	IIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION: 200' - 500' AREA: 5 - 100 acres SLOPE: 0-3%

1. Poorly drained, fine textured soils formed from silty and clayey mixed alluvium. The surface layer is a silty clay loam about 14' thick. The subsoil is mottled clay about 27 inches thick. The substratum is stratified clay loam, loam, and sandy loam.
2. Occupy nearly level and slightly depressed areas along drainageways.
3. Associated with Coburg and Malabon soils.
4. Water movement is restricted by the slow permeability of the subsoil.
5. The subsoil has slow permeability. The substratum below the subsoil has moderate permeability.

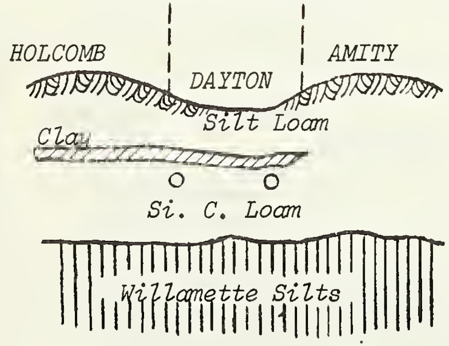
DRAINAGE PROBLEMS AND CONSIDERATIONS

Soil surface is subject to ponding.
Surface drainage will relieve ponding and speed runoff.
Tile should be placed below the clay layer.
Effectiveness of subsurface drainage is affected by the clay layer.
Filter placement and backfill are important.
Install tile when soil is dry to keep compaction and reduction in the permeability of the clay to a minimum.
Improvement of natural drainageways should be considered.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL
Surface Drainage							
Field ditches			300' maximum spacing			1½	3.0
Land grading			700' maximum length				
Bedding			70 to 90' by 700'				
Subsurface Drainage							
Closed pattern drainage			40 to 80'	3.5 to 5'	Ia or IIa & IIIa		

DAYTON

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 150-400'   AREA - 5-over 40 ac.   SLOPE - 0-3%

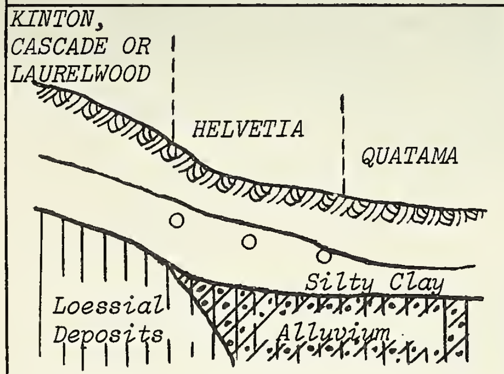
1. Poorly drained, very deep soil with light gray silt loam over light brownish gray clay pan that rests on silty clay loam.
2. Occurs on low, level to concave areas on the terrace.
3. Associated with Holcomb, Amity and Concord.
4. Downward movement of water restricted by clay pan.
5. Slow permeability in clay pan subsoil at 16 to 22 inches. Moderately slow permeability in substrata of willamette silts below 40 to 50 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Soil surface is subject to ponding.
Surface drainage will relieve ponding and speed runoff.
Tile should be placed below the clay layer.
Effectiveness of subsurface drainage is affected by the clay pan.
Filter placement and backfill are important.
Improvement of natural drainageways should be considered.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Surface Drainage							
Field ditches			300' maximum spacing			1 1/2	3.0
Land grading			700' maximum length				
Bedding			70 to 90' by 700'				
Subsurface Drainage							
Closed pattern drainage			40 to 60'	3.5 to 5'	Ia or IIa & IIIa		
Relief drains			In natural drainageway or for outlet	3.5 to 5'		1 1/2	3.0

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 240-500' AREA - 10-over 40 ac. SLOPE - 0-20%

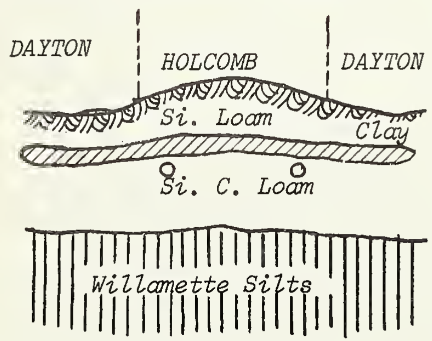
1. Well to moderately well drained, deep soil with dark brown silt loam over dark brown mottled silty clay with slightly compacted layers.
2. Occurs in depressions on terraces bordering the uplands.
3. Associated with Cascade, Kinton and Laurelwood on uplands and with Quatama on terraces.
4. Wetness due to position and slow permeability of substrata.
5. Moderately slow permeability in silty clay subsoil below 18 to 30 inches. Slow permeability in substrata of alluvium below 48 to 60 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception drainage is recommended.
This soil occurs in extensive areas and pattern drainage is recommended on flatter slopes (5 to 8%).
Porous backfill should extend above the fragipan layer.
Random tile drainage may be feasible to relieve individiaul wet areas.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX.VEL (f.p.s.)
Subsurface Drainage							
Interception drainage (open or closed)			At upper edge of seepage area	3.5 to 5'	Ia or IIa & IIIc	1 1/2	3.0
Closed pattern drainage			55 to 65'	3.5 to 4.5'	IIa & IIIc		
Closed random drainage			In depressional wet areas	3 to 5'	IIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 200-400' AREA - 5-over 40 ac. SLOPE - 0-3%

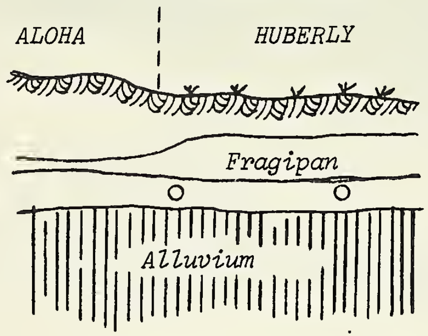
1. Somewhat poorly to poorly drained, deep, dark brown, silt loam over clay over silty clay loam.
2. Occurs on slightly higher undulations in areas of Dayton on the terraces.
3. Associated with Amity, Concord, and Dayton.
4. Downward movement of water is stopped by the layer of clay.
5. Slow permeability in clay subsoil below 18 to 24 inches. Moderate slow permeability in substrata of Willamette silt deposit, below 36 to 48 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Occurs in flat areas of convex slope.
Both surface and subsurface drainage are feasible.
Tile should be placed beneath the clay layer and backfill with previous topsoil or other material to above the clay layer.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX.VEL (f.p.s.)
Surface Drainage							
Field drains			300' maximum spacing			2	3.0
Land smoothing			Remove adverse slopes and depressional areas				
Subsurface Drainage							
Closed pattern drainage			50 to 70'	3.5 to 5'	IIIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

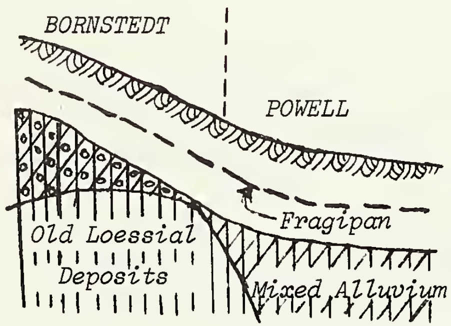
ELEVATION - 150-240'   AREA - 5-15 ac.   SLOPE - 0-1%

1. Poorly drained, deep soil with very dark gray silt loam over dark grayish brown and gray silt loam and silty clay loam with strongly compacted layers.
2. Occurs in swales and basins on the terrace adjacent to uplands.
3. Associated with Quatama and Aloha soils.
4. Wetness due to position, contribution of water from higher lying areas and to restricted permeability in compacted layers.
5. Moderately slow permeability in subsoil below 15 to 24 inches. Slow permeability in lower subsoil below 36 to 48 inches. Moderately slow permeability in substrata of silt alluvium below 48 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Subsurface and surface methods of drainage are recommended.
The fragipan layer is very defined and a pervious filter and backfill are important for closed drainage.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN	
						Z	MAX.VEL (f.p.s.)
Subsurface Drainage							
Interception drainage (open or closed)			At contact with higher soil bodies	3.5 to 5'	Ia or IIa & IIIc	1 1/2	3.5
Closed pattern drainage			40 to 50'	3.5 to 4.5'	IIa & IIIc		
Closed random drainage			In depressional wet areas	3 to 5'	IIa & IIIc		
Surface Drainage							
Field ditches			300' maximum spacing			1 1/2	3.5
Land smoothing			Remove adverse slopes and field depressions				

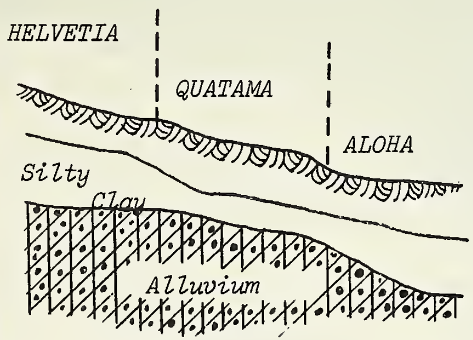
SOIL ASSOCIATION SKETCH	PHYSICAL FACTORS IN SOIL PROFILE
	ELEVATION - 150-400' AREA - 20-30 ac. SLOPE - 0-7% 1. Somewhat poorly drained, deep soil with dark yellowish brown silt loam over yellowish brown, highly mottled silt loam with strongly compacted layers. 2. Occurs on terraces adjacent to the uplands. 3. Associated with Bornstedt on the uplands. 4. Wetness due to restricted permeability in compacted layers. 5. Moderately slow permeability in lower subsoil below 40 to 50 inches. Slow permeability in substrata of silty alluvium below 50 to 60 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

This soil occurs in extensive areas and pattern drainage is recommended.
Interception drainage should be considered when permitted by topographic conditions.
Surface drainage can be considered on flatter phases of this soil.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX.VEL (f.p.s.)
Subsurface Drainage							
Closed pattern drainage			60 to 80'	3.5 to 4.5'	IIa & IIIc	1 1/2	3.5
Interception drainage (open or closed			At contact with higher soil bodies or field boundaries	3.5 to 5'	IIa & IIIc		
Surface Drainage							
Field ditches			400' maximum spacing			1 1/2	3.5
Land smoothing			Remove adverse slopes and field depressions				

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 140-200' AREA - 15-over 40 ac. SLOPE - 0-20%

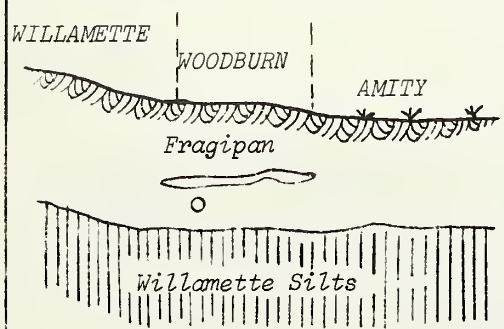
1. Moderately well drained, deep soil with dark brown, silt loam over dark brown silty clay loam.
2. Occurs on gentle slopes in swale positions on terraces adjacent to uplands.
3. Associated with Helvetia, Woodburn, Aloha and Huberly.
4. Wetness due to movement of subsurface water into soil from higher lying areas.
5. Moderately slow permeability in lower subsoil below 40 to 50 inches. Moderate permeability in substrata of alluvium below 50 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Interception drainage is recommended when adjacent to Helvetia or determined by investigation. Pattern drainage is feasible when needed in this moderately well drained soil.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX.VEL (f.p.s.)
Subsurface Drainage							
Interception drainage (open or closed)			At contact with higher soil body	3.5 to 5'	IIa & IIIc	1 1/2	3.0
Closed pattern drainage			70 to 80'	3.5 to 4.5'	IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 150-400' AREA - 30-over 40 ac. SLOPE - 0-20%

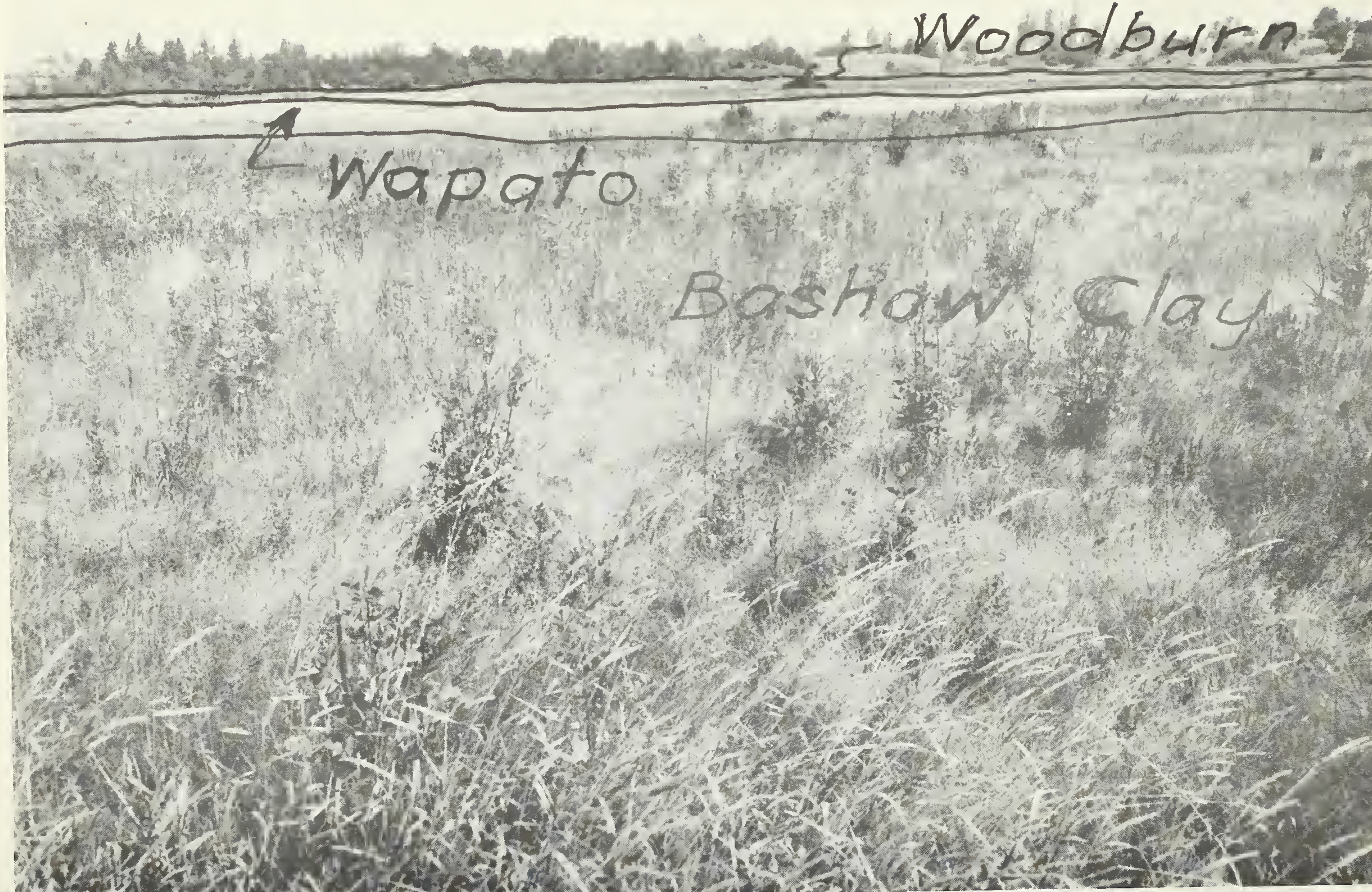
1. Moderately well drained, very deep soil with dark brown silt loam over mottled, dark yellowish brown silty clay loam with 2" to 4" layers of slightly compacted fragipan below 30 inches.
2. Occurs on smooth gently sloping terraces of Willamette silts.
3. Associated with the well drained Willamette, the somewhat poorly drained Amity and Holcomb, and poorly drained Dayton soils.
4. Wetness due to restriction in permeability in fragipan or stratification below 20".
5. Moderately slow permeability through fragipan layers in silty clay loam subsoil below 20 to 36 inches. Moderate permeability in substrata of Willamette silts below 50 to 72 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Closed pattern drainage is recommended for improved drainage or flatter slopes.
Closed random tile may be used to relieve wetter areas.
Surface methods will improve drainage on flatter slopes.
Fragipan is principle restriction to drainage.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX.VEL (f.p.s.)
Subsurface Drainage							
Closed pattern drainage			70' to 80'	3.5 to 5'	IIIa & IIIc		
Closed random drainage			In depressional wet areas	3.5 to 5'	IIa & IIIc		
Surface Drainage							
Field ditches			500' maximum spacing			2	3.0
Land smoothing			Remove adverse slopes and field depressions				
Land grading			Grade flat areas to nearest drain				

Drainage work in progress on Amity soil. (Photo No. 0-883-11)



Typical vegetation on Bashaw clay in Hoffman Bottoms near Mt. Angel. Associated soils are Woodburn and Wapato. (Photo No. 0-1439-7)

III. TERRACE SOILS

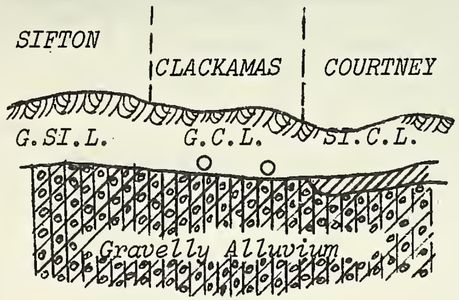
B. ADJACENT TO BROAD VALLEY FLOOD PLAIN

1. Clackamas (sp)

2. Courtney (p)

3. Natory (p)

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 175-650'   AREA - 10-over 40 ac.   SLOPE - 1-3%

1. Somewhat poorly drained, moderately deep to deep, very dark brown, gravelly silt loam over a yellowish brown gravelly clay loam over compacted gravels.
2. Occurs on low alluvial terraces adjacent to the floodplain.
3. Usually associated with Sifton and Courtney.
4. Downward movement of water is restricted by compact gravels with clay loam matrix.
5. Slow permeability in gravelly clay subsoil below 16 to 24 inches. Very slow permeability in compacted gravelly substrata below 30 to 48 inches.

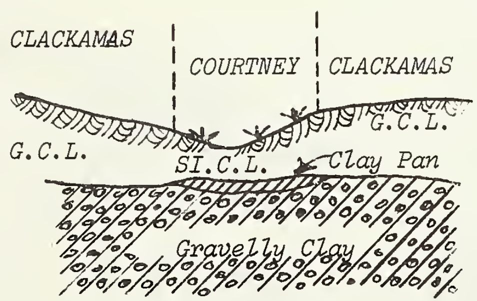
DRAINAGE PROBLEMS AND CONSIDERATIONS

Closed subsurface drainage is recommended.
Depth of closed drains should be at or in the compacted gravels.
Interception drainage is not normally required.
The gravelly subsoil may be more pervious at greater depths.
Surface methods will improve drainage where runoff is slow.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Subsurface Drainage							
Closed pattern drainage			50 to 70'	3 to 4'	IIa & IIIc		
Closed random drainage			In depressional wet areas	3 to 4'	IIa & IIIc		
Surface Drainage							
Field ditches			400' maximum spacing			2	4.0
Land grading			700' maximum length				

COURTNEY

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

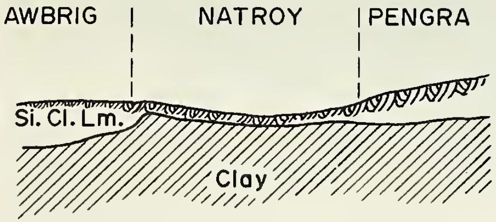
ELEVATION - 300' AREA - 5-10 ac. SLOPE - 0-3%

1. Poorly drained, deep soils with very dark brown silty clay over variegated gravelly clay.
2. Occurs in depressions and along drainageways on low alluvial terraces.
3. Usually associated with Clackamas and Sifton.
4. Downward movement of water is restricted by clay pan over compact gravels with clay matrix.
5. Slow permeability in clay subsoil below 12 to 20 inches. Very slow permeability in massive clay substrata below 40 to 50 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Needs improved surface drainage.
Improved natural drainageways should be considered.
Tile drainage of adjacent soils should also be considered.
Closed subsurface drainage is not feasible.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX.VEL (f.p.s.)
Surface Drainage							
Field ditches			200' maximum spacing			2	3.0
Land smoothing			On steeper slopes to remove adverse slope and field depressions				
Land grading			Grade flat areas to nearest drain				
Subsurface Drainage							
Open relief drains			In drainageways	3 to 5'		2	3.0

SOIL ASSOCIATION SKETCH	PHYSICAL FACTORS IN SOIL PROFILE
	ELEVATION: 300-700' AREA: 2-200 acres SLOPE: 0-3% 1. Poorly drained, clay soils formed in recent clayey alluvium. The surface layer is a silty clay loam about 4 inches thick. The subsurface is clay about 28 inches thick. The substratum to 60 inches is clay. 2. Occupy nearly level basins and slightly concave drainageways. 3. Associated with Awbrig, Conser, Courtney, Dayton, and Pengra soils. 4. Water movement is restricted by the very fine textured profile. 5. Very slow permeability in the subsoil and substratum.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Surface drainage is recommended.
Tile drainage is not feasible.
Natural drainageways should be improved and open ditches may be necessary for outlet of surface drainage.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX.VEL
Surface Drainage							
Field ditches Land grading Bedding			200' maximum spacing Slope to natural outlets 60 to 80' by 600'			1½	3.5
Subsurface Drainage							
Open relief drainage			Natural drainageways or as surface drainage outlet	3 to 4'		1½	3.5

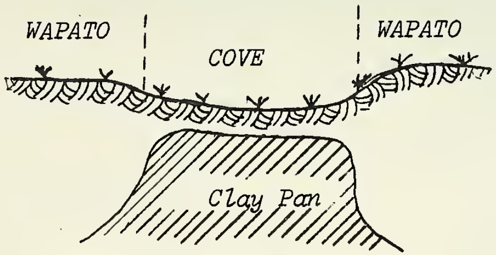
Clackamas soil associated with Sifton. (Photo No. 0-1406-9)

Courtney soils in foreground in association with Clackamas.
(Photo No. 0-1366-12)

IV. BROAD VALLEY FLOOD PLAIN SOILS

1. Cove (p)
2. Labish (p)
3. McBee (mw)
4. Moag (vp)
5. Rafton (vp)
6. Sauvie (p)
7. Semiahmoo (vp)
8. Verboort (p)
9. Wapato (p)

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 150-400' AREA - 5-10 ac. SLOPE - 2% or less

1. Poorly drained, very deep, mottled soil with very dark brown silt to silty clay loam over clay that rests on silty clay.
2. Occurs on concave slopes on the broad floodplain generally adjacent to the terrace front of Willamette silts.
3. Usually associated with McBee and Wapato.
4. Wetness is due to position, high permanent water table that fluctuates with stream level, overflow and with very slow permeability.
5. Slow permeability in clay subsoil below 10 to 20 inches. Moderately slow permeability in silty clay substrata below 50 to 60 inches.

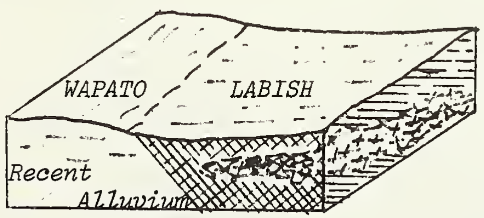
DRAINAGE PROBLEMS AND CONSIDERATIONS

Enlargement of natural channels and improved surface drainage are recommended to reduce frequency and duration of overflow and ponding.
Tile drainage is not normally practicable.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN	
						Z	MAX.VEL (f.p.s.)
Surface Drainage							
Relief drains			In drainageways	3 to 5'		2	4.0
Field ditches			300' maximum spacing				
Bedding			70 to 90' by 700'				
Land grading			Grade toward ditches				
Subsurface Drainage							
Pattern drains			40 to 50'	3 to 5'	Ib, IIa		

LABISH

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 150-175' AREA - 5-over 40 ac. SLOPE - 0%

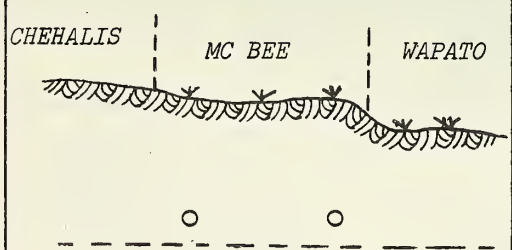
1. Poorly drained, very deep. black, silty clay loam surface with peaty material over very dark gray clay that may contain peat layers or have a peat substratum.
2. On level lakebeds and basins.
3. Associated with Wapato and Cove soils.
4. Wetness due to position, high permanent water table, overflow and slow permeability.
5. Moderately slow permeability in upper 16"; slow in clayey horizons.

DRAINAGE PROBLEMS AND CONSIDERATIONS

High water table, restricted outlet conditions, flat surface topography occupies lower part of lakebeds or basins.
Water control necessary to control oxidation of peat materials.
Pumped outlets recommended to control rate of withdrawal of soil water.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Subsurface Drainage							
Closed pattern drains			40 to 50'	4 to 5'	IIa & IIIc		
Surface Drainage							
Land grading Field ditches			Grade toward ditches 80 to 200'	1 to 2'		1/4	2.0
Water Control structures Pumped outlets							

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 25-500'   AREA - 15-over 40 ac.   SLOPE - 2% or less

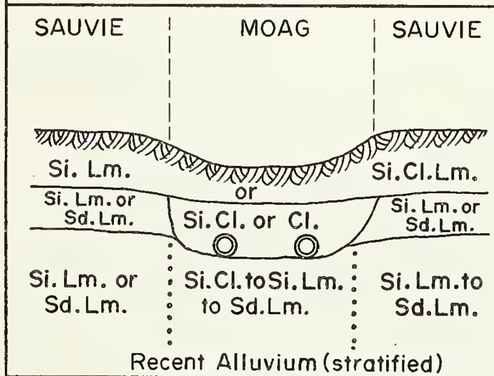
1. Moderately well drained, very deep, very dark brown silt loam or silty clay loam over mottled silty clay over stratified alluvium.
2. Occurs in intermediate position on floodplain on level to gentle slopes.
3. Associated with Chehalis and Wapato.
4. Wetness is due to permanent water table that fluctuates with stream level.
5. Moderately slow permeability in silty clay subsoil below 14 to 24 inches. Moderate permeability in subsoil below 36 inches and in substrata of recent alluvium.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Closed subsurface drainage is recommended for optimum use of this soil.
Enlargement and deepening of natural channels or establishment of an outlet is normally needed to provide relief from water table conditions.
Improved surface drainage is needed to reduce inundation and prolonged flooding.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX.VEL (f.p.s.)
Subsurface Drainage							
Closed pattern drainage			70 to 90'	3.5 to 4.5'	IIIa & IIIc		
Closed random drainage			In depressional areas	3 to 5'	IIIa & IIIc		
Open relief drain			In drainageway or for outlet	3.5 to 5'		1 1/2	3.0
Surface Drainage							
Field ditches			400' maximum spacing			1 1/2	3.0
Land smoothing			Remove adverse slopes and field depressions				
Land grading			Grade toward ditches				

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION: 10-20' AREA: 5-300 Acres SLOPE: 0-2%

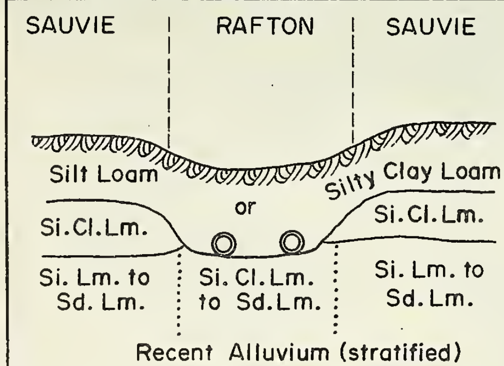
1. Very poorly drained, deep soil with dark grayish brown silty clay loam over dark grayish brown silty clay.
2. Occurs on broad nearly level undulating flood plains of the Columbia River.
3. Associated with Rafton and Sauvie.
4. Saturated throughout the year and subject to fresh water overflow during high tides and spring floods unless diked. Often ponded.
5. Slow permeability throughout profile.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Enlargement and deepening of natural outlet channels is recommended.
Dike to exclude high water from tides and floods where necessary.
Improve surface drainage to move water off the land and reduce ponding.
Pattern drains are recommended to lower water table.
Use flapgates and/or pumps as needed.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL
Surface Drainage							
Field ditches			300' maximum spacing			1½	3.0
Bedding			70 to 90' by 800'				
Land grading			Grade toward ditches				
Subsurface Drainage							
Closed pattern drains			50-70'	3.5 - 4.5'	IIIa & IIIc		
Closed random drains			In depressional areas	3 - 5'	IIIa & IIIc		
Open relief drains			In drainageway or for outlet	3.5 - 5'		1½	3.0

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION; 10-20' AREA: 5-500 acres SLOPE: 0-2%

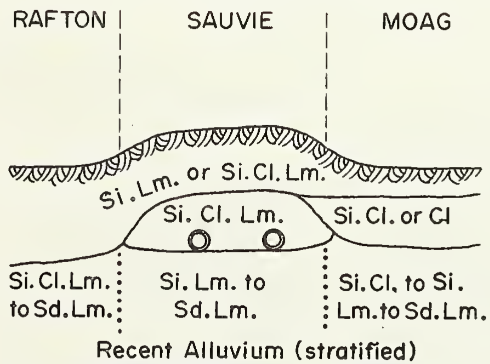
1. Very poorly drained, deep soil with gray brown to dark gray silt loam from 0-60 inches.
2. Occurs on broad nearly level undulating flood plains of the Columbia River.
3. Associated with Sauvie and Moag.
4. Saturated throughout the year and subject to fresh water overflow during high tides and spring floods unless diked. Often ponded.
5. Moderate permeability throughout profile.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Enlargement and deepening of natural outlet channels is recommended.
Dike to exclude high water from tides and floods where necessary.
Improve surface drainage to move water off the land and reduce ponding.
Pattern drains are recommended to lower water table.
Use flapgates and/or pumps as needed.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL
SURFACE DRAINAGE							
Field ditches			400' maximum spacing			1½	3.0
Bedding			80 to 100' by 800'				
Land grading			Grade toward ditches				
Subsurface Drainage							
Closed pattern drains			60 - 80'	3.5 - 4.5'	Ia, IIIa, IIIc or IVa		
Closed random drains			In depressional areas	3 - 5'	Ia, IIIa, IIIc or IVa		
Open relief drains			In drainageway or for outlet	3.5 - 5'		1½	3.0

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION: 20-40'   AREA: 5-500 acres   SLOPE: 0-3%

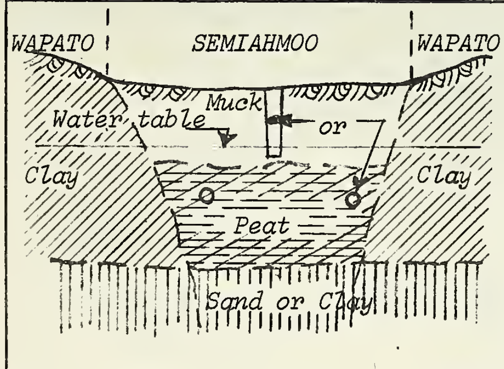
1. Poorly drained, very deep soil with very dark grayish brown, silty clay loam or silt loam over a dark grayish brown very fine sandy loam subsoil.
2. Occurs on nearly level to gently undulating flood plains along the lower Columbia River and its tributaries.
3. Associated with Moag and Rafton.
4. Saturated seasonally and subject to fresh water overflow during high tides and spring floods unless diked.
5. Moderately slow permeability from 0-39 inches and moderately rapid permeability from 39-60 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Enlargement and deepening of natural channels is recommended.
Dike to exclude high water from tides and floods where necessary.
Improve surface drainage to move water off the land.
Pattern drains are recommended to lower water table.
Use flapgates and pumps as needed.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN	
						Z	MAX. VEL
Surface Drainage							
Field ditches			350' maximum spacing			1½	2.5
Bedding			80 to 100' by 800'				
Land grading			Grade toward ditches				
Subsurface Drainage							
Closed pattern drains			60 to 80'	3.5 to 4.5'	Ia, IIIa, IIIc or IVa		
Closed random drains			In depressional areas	3 to 5'	Ia, IIIa, IIIc or IVa		
Open relief drains			In drainageway or for outlet	3.5 to 5'		1½	2.5

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 0-200' AREA - 1-200 ac. SLOPE - 0-1%

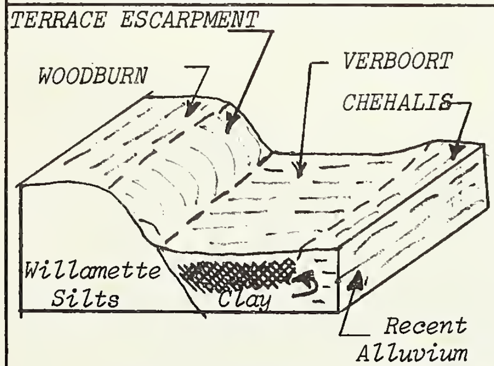
1. Poorly drained bog soils, muck to about 2 feet underlain with fibrous peat over sand or clay.
2. Occurs in basins with restricted outlets.
3. Associated with Labish clay, Wapato, and other swampland soils.
4. Water table 18 to 30 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Topography is nearly flat, basins have restricted drainage outlets.
Permeability is moderate.
Underlain with woody peat.
Needs water level control system to minimize subsidence.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Subsurface Drainage							
Closed pattern drains			40 to 60'	4 to 5'	IIa & IIIc		
Surface Drainage							
Field ditches			200 - 400'	1 to 1.5'		1/4	2.0
Land grading			Grade toward ditches				

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 150-300' AREA - 10-over 40 ac. SLOPE - 0-3%

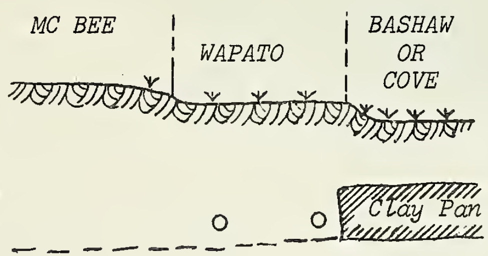
1. Poorly drained, very deep soil with very dark brown silty clay loam over very dark gray clay that rests on silty clay loam.
2. Occurs on long, narrow stream bottoms on concave or level slopes.
3. Associated with Chehalis, Wapato, Woodburn, and Helvetia soils.
4. Wetness due to perched water table over clay or silty clay and some overflow.
5. Moderately slow permeability in upper part, slow at less than 20 inches, moderately slow below 36 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Enlargement and deepening of natural outlet channels are recommended.
Needs improved surface drainage to move water off land and reduce ponding.
Tile should be placed beneath the clayey layer and backfill with previous topsoil or other material to above the clayey layer.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN	
						Z	MAX.VEL (f.p.s.)
Surface Drainage							
Field ditches			300' maximum spacing			1½	3.5
Land grading			Grade toward ditches				
Subsurface Drainage							
Closed pattern drainage			40 to 50'	3.5 to 5'	IIIa & IIIc		
Closed random drainage			In depressional areas	3 to 5'	IIIa & IIIc		

SOIL ASSOCIATION SKETCH



PHYSICAL FACTORS IN SOIL PROFILE

ELEVATION - 100-300' AREA - 10-over 40 ac. SLOPE - 2% or less

1. Poorly drained, deep soil with very dark gray silt or silty clay loam over dark gray silty clay that rests on silty clay loam.
2. Occurs in depressed areas on floodplains on gently concave and level slopes.
3. Associated with McBee, Cove, Bashaw, or Labish.
4. Wetness is due to permanent water table that fluctuates with stream level, overflow, and excessive rainfall.
5. Moderate permeability in silty clay subsoil below 18 to 30 inches. Moderately rapid permeability in substrata of silty alluvium below 40 to 50 inches.

DRAINAGE PROBLEMS AND CONSIDERATIONS

Enlargement and deepening of natural outlet channels is recommended.
This soil needs improved surface drainage to move water off the land and reduce ponding.
Pattern tile drainage is recommended to lower the water table.

APPLICABLE DRAINAGE METHODS	DRAINAGE COEFFICIENT	HYDRAULIC CONDUCTIVITY	LOCATION OR SPACING	DEPTH	FILTER	OPEN Z	OPEN MAX. VEL (f.p.s.)
Surface Drainage							
Field ditches			400' maximum spacing			1½	3.0
Bedding			80 to 100' by 800'				
Land grading			Grade toward ditches				
Subsurface Drainage							
Closed pattern drainage			40 to 50'	3.5 to 4.5'	IIIa & IIIc		
Closed random drainage			In depressional areas	3 to 5'	IIIa & IIIc		
Open relief drains			In drainageway or for outlet	3.5 to 5'		1 1/2	3.0

Onion production on Semiahmoo Muck in Lake Labish basin.
(Photo No. F-425-7)

The Wapato - McBee - Chehalis association. Mint is on the McBee silty clay loam. (Photo No. 0-1406-1)

EXAMPLES

The use of the soil association sketch and design information sheets contained in Part II and the design information contained in the Appendices can best be shown by example. Two examples of typical drainage designs are given.

Example No. 1 consists of a 22-acre field that is subject to precipitation and, on occasion, overbank flooding. It is also necessary to provide an outlet since no suitable natural one exists.

Example No. 2 consists of a surface drainage system and a subsurface drainage system on a 21-acre field.

COMPUTATION SHEET
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U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
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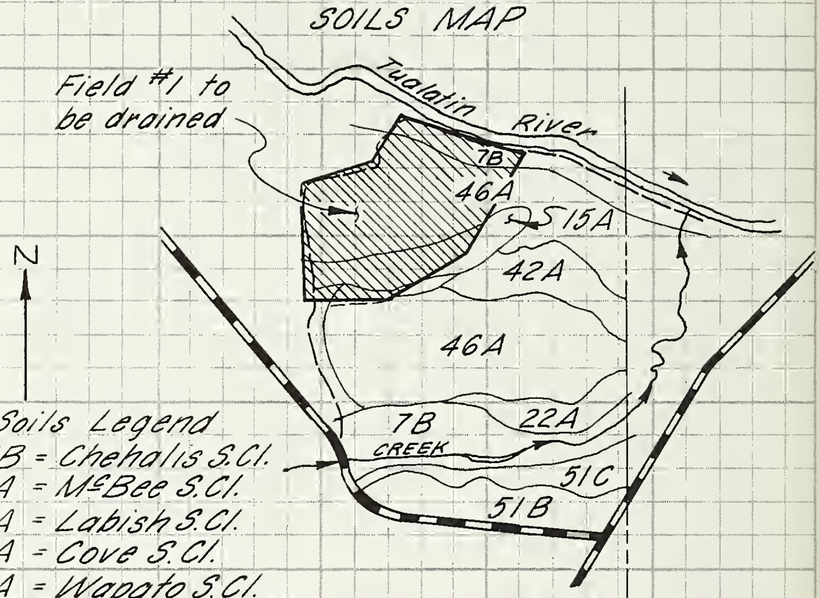
Washington County SWCD

STATE Oregon		PROJECT Drainage System – J. Stout		
BY H.J.W.	DATE 10-26-71	CHECKED BY	DATE	JOB NO.
SUBJECT Example #1 – Field Drain Design				SHEET 1 OF 6

BASIC DATA

SOILS MAP

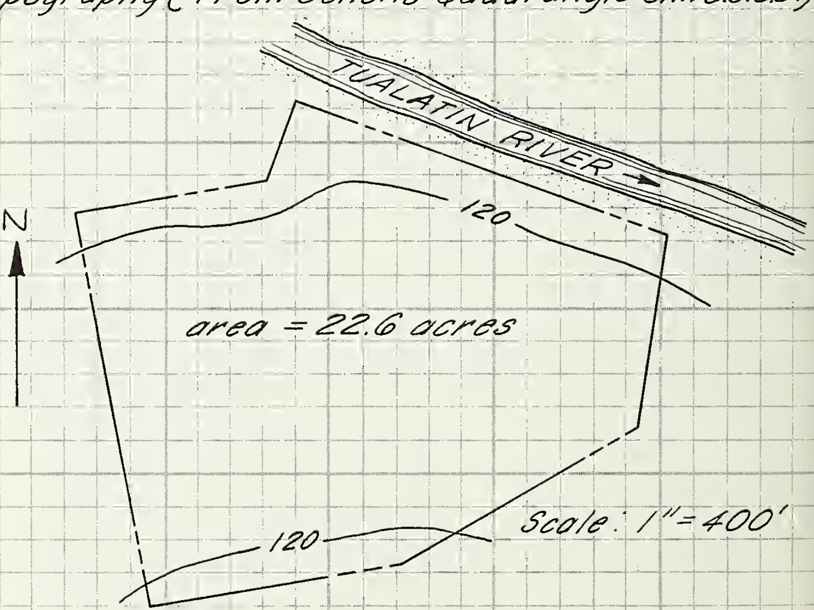


Soils Legend
7B = Chehalis S.Cl.
22A = McBee S.Cl.
15A = Labish S.Cl.
42A = Cove S.Cl.
46A = Wapato S.Cl.
51B = Woodburn S.l.
51C = Woodburn S.l.

T2S, R2W, WM

scale 3.85" = 1 mile
1" = 1,370'

Topography (from Scholls Quadrangle sht. U.S.G.S.)



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SOIL CONSERVATION SERVICE

Washington County S.W.C.D.

STATE Oregon	PROJECT Drainage System – J. Stout		
BY H.J.W. DATE 10-26-71	CHECKED BY	DATE	JOB NO.
SUBJECT Example #1 - Field Drainage Design			SHEET 2 OF 6

Water surface in river will be above drain outlet elevation during many months. Drain outlet will need to be pumped. Surface drainage water must be taken care of.

Use open channel for main outlet, provide culvert with flapgate at outlet thru river bank.

Soils are Wapato Silty Clay Loam with a small amount of Labish on South edge of field.

Crops to be grown
- Onions
- Green Beans
- Corn
- Pasture - grass

Applicable practices from Willamette Valley Drainage Guide for Wapato (pg.143) and Labish (pg.136).

Surface drainage practices which are applicable.
Drainage Field Ditches – 400' max. spacing
Bedding –
Drainage Land Grading – slope toward field ditches
Drainage Main or Lateral – for ditch outlet

Sub-surface drainage practices which are applicable.

Pattern drains – 3.5' to 4.5' deep, 80' – 100' spacing for Wapato, 40' – 60' for Labish

Pumping plant – needed at river end of outlet drain to effect water table control.

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Washington County S.W.C.D.

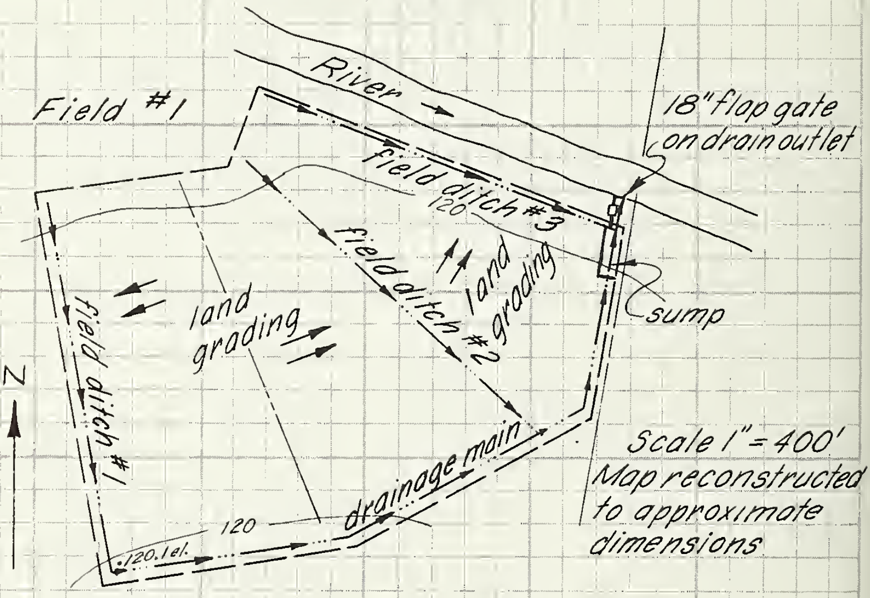
STATE Oregon		PROJECT Drainage System - J. Stout		
BY H.J.W.	DATE 10-26-71	CHECKED BY	DATE	JOB NO.
SUBJECT Example #1 Field Drain Design				SHEET 3 OF 6

SOLUTION

Since overbank flooding and surface ponding will occur during the rainy season a surface drainage system will be used. Land grading and field ditches will minimize depressional storage.

A closed pattern system of 4" diameter drain tile will also be used. Drain spacing will be 80' in Wapato, 40' in Labish. Use a sump with pump at outlet.

Proposed Surface Drainage System



Determine surface runoff of the 22.6 acres.

Using W.V.D.G. - Fig. 6, Curve 1 the Q is 3.3 cfs.

$\frac{3.3}{3} = 1.1$

Assume eash of the three field ditches will have a Q of 1.1 cfs.

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SOIL CONSERVATION SERVICE

Washington County S.W.C.D.

STATE Oregon		PROJECT Drainage System - J. Stout		
BY H.J.W.	DATE 10-26-71	CHECKED BY	DATE	JOB NO.
SUBJECT Example #1 - Field Drainage Design				SHEET 4 OF 6

Determine dimensions of field ditches

	Q	=	1.1 cfs
from field survey	S	=	0.001 ft/ft.
assumed	n	=	0.04
for ease of O&M	Z	=	4:1
for Labish	Vmax.	=	2.0 f.p.s.

From charts in W.V.D.G., Appendix C Select.

b = 2
d = 0.5 (use 1.0' min.)
V = 0.55 fps < 2.0 OK

Determine dimension of drainage main.

Max. condition	Q	=	3.3 cfs
from field survey	S	=	0.00081 ft/ft.
Assumed	n	=	0.04
1/4:1 OK for Labish	Z	=	1:1
For Labish soil	Vmax.	=	2.0

From charts in W.V.D.G., Appendix C Select.

b = 2
d = 1.2
V = 0.9 < 2.0 OK

Armco Hdbk. — The drainage main will outlet into sump which in turn outlets thru 18" Culvert equipped with flap gate.

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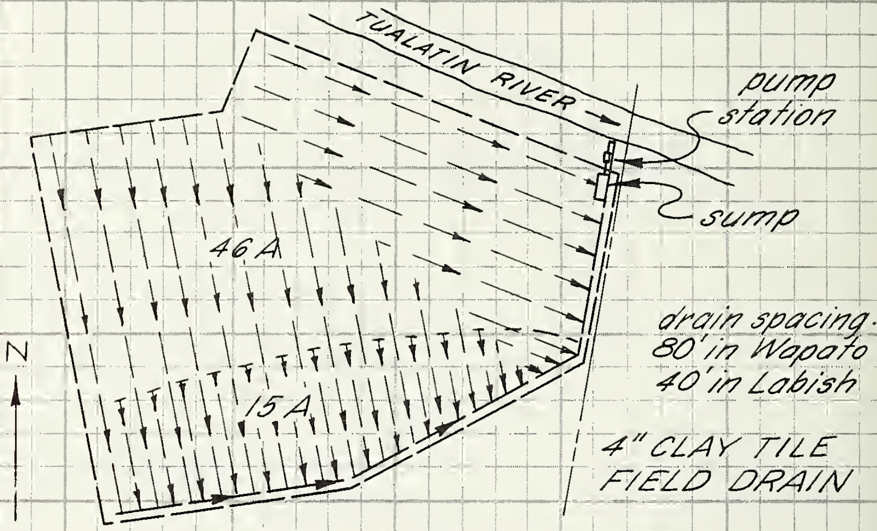
Washington County S.W.C.D.

STATE Oregon		PROJECT Drainage System - J. Stout		
BY H.J.W.	DATE 10-26-71	CHECKED BY	DATE	JOB NO.
SUBJECT Example #1 Field Drain Design				SHEET 5 OF 6

Proposed Subsurface Drainage System



Scale 1" = 400'

Determine Mainline Size

$S = 0.0008$ ft/ft or 0.081 ft/100 ft

Use Tile Drainage Chart in W.V.D.G., Appendix D

Select 8" for first 800' and 6" for remander of line. using coef. of 3/8"

Owner has 1 cfs pump available

Evaluate

Drainage Q in growing season to remove 3/8" per day

$1 \text{ cfs} = 24 \frac{\text{ac-in}}{\text{day}}$

$$Q = (22.6 \text{ acres})\left(3/8 \frac{\text{in}}{\text{day}}\right) = 8.48 \frac{\text{ac-in}}{\text{day}}$$

$$= 0.35 \text{ cfs}$$

Pump will operate about 35% of the time.
To minimize on-off operation install sump.

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Washington County-SWCD

STATE Oregon		PROJECT Drainage System- J. Stout		
BY H.J.W.	DATE 10-26-76	CHECKED BY	DATE	JOB NO.
SUBJECT Example #1 - Field Drain Design				SHEET 6 OF 6

Water will drain thru 18" culvert with flap gate. The gate will close when pump lowers water surface in the sump below river level.

Pump will remove $\frac{24}{22.6}$ = 1.07" per day with full time operation.

S.C.S. Standard	Minimum slope tile drains S = 0.0005
See W.V.D.G. page 143 and Appendix D page 197 & 198	Envelop and backfill materials

Wapato - Type IIIa and IIIc
Use select soil envelope and backfill with excavated material.

Labish - Use organic envelope and backfill with excavated material.

Construction Quantities

12,580 ft.	=	4" tile or tubing
800 ft.	=	6" tile or tubing
800 ft.	=	8" tile or tubing
1,000 CY	=	ditch excavation
750 CY	=	sump excavation
3 CY	=	concrete
60 LF	=	18" coated CMP with 2 cut-off collers
1	=	18" flap gate
1	=	pump, motor, controls & shelter

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U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Linn-Lane SWCD

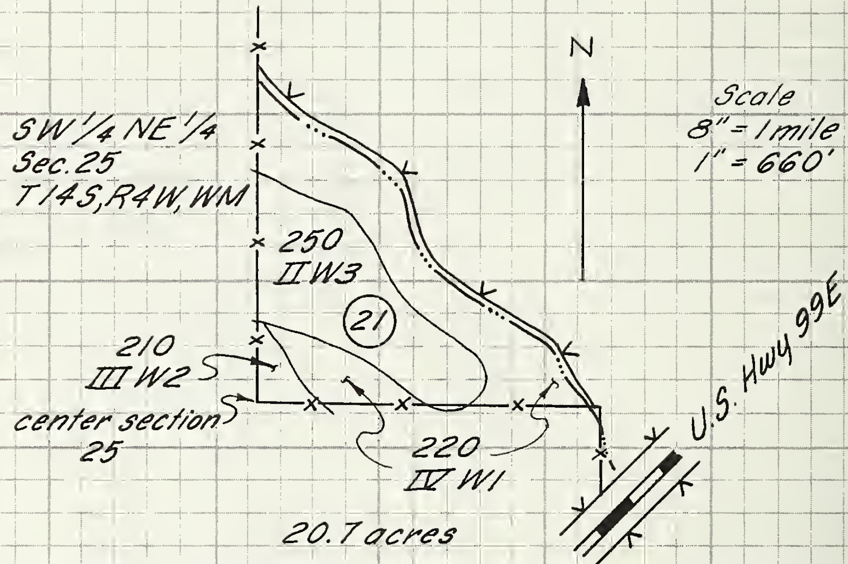
STATE Oregon		PROJECT Farm Drainage - John Doe		
BY H.J.W.	DATE 11/5/71	CHECKED BY	DATE	JOB NO.
SUBJECT Example #2 - Field Drain Design				SHEET 1 OF 5

BASIC DATA

Land Use Map

300+ acre farm near Halsey, Oregon. Farm plan indicates field 21 is to be drained.

Soils map for field 21 is as follows.



Soils Legend		Capability Unit
210	Concord Silt Loam	III W2
220	Dayton Silt Loam	IV W1
250	Woodburn Silt Loam	II W3

Crops

Dayton Silt Loam
- Common Ryegrass - Seed
- Sweet Corn - irrigated
- Blackberries - irrigated

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SOIL CONSERVATION SERVICE

Linn-Lane SWCD

STATE Oregon	PROJECT Farm Drainage- John Doe		
BY H.J.W. DATE 11/5/71	CHECKED BY	DATE	JOB NO.
SUBJECT Example #2 Field Drain Design			SHEET 2 OF 5

Concord Silt Loam
Grass Pasture

Woodburn Silt Loam
Sweet Corn
Blackberries
Strawberries
Alfalfa
Grass Pasture

Surface Drainage

Specifications for surface drainage are as follows:

See W.V.D.G. page 122

Woodburn
Field ditches - 500 ft. max. spacing
Land grading
Land smoothing

See W.V.D.G. page 116

Dayton
Field ditches - 300 ft. max. spacing
Land grading - 700 ft. max. length bedding
Bedding - 70 ft. to 90 ft. by 700 ft.

See W.V.D.G. page 114

Concord
Field ditches - 300 ft. max. spacing
Land grading - slope to ditch or outlet
Bedding - 70 ft. to 90 ft. by 700 ft.

Field 21 sketch will be enlarged to facilitate planning.

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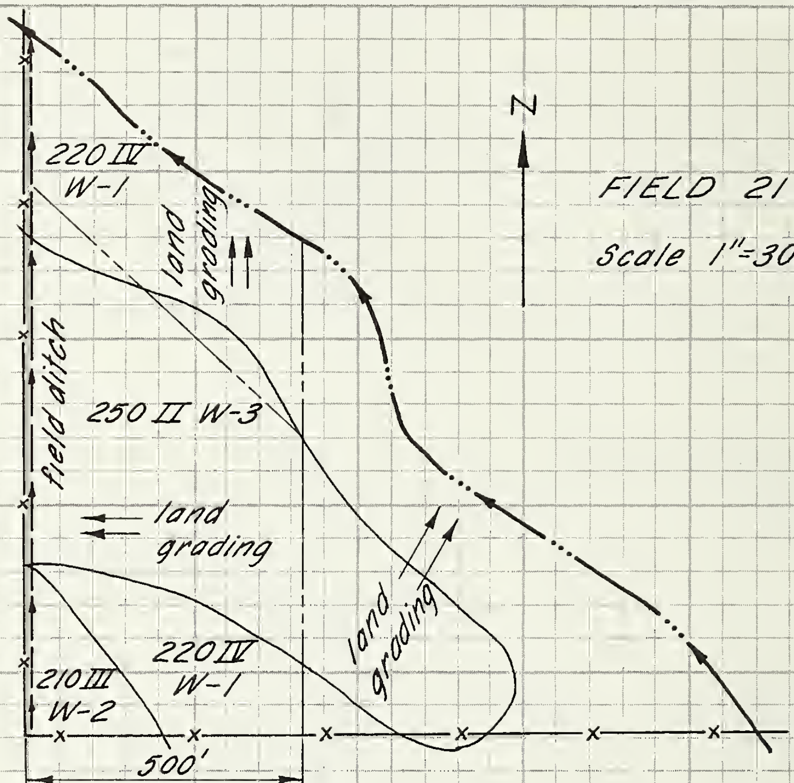
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Linn - Lane SWCD

STATE Oregon		PROJECT Farm Drainage - John Doe		
BY H.J.W.	DATE 11/9/71	CHECKED BY	DATE	JOB NO.
SUBJECT Example #2 Field Drain Design				SHEET 3 OF 5



The layout of the recommended surface system is shown above.

SUBSURFACE DRAINAGE

The specifications for subsurface drainage are as follows:

see W.V.D.G. page 122, and appendix D page 197 & 198

Woodburn
Closed pattern drainage
drains 80'-100' spacing 3.5±5.0' deep

Bedding, Filter, Envelope, and Backfill
Materials IIIa & IIIc
Bedding - Selected topsoil
Blinding - (same)
Backfill - trench run material

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SOIL CONSERVATION SERVICE

Linn-Lane SWCD

STATE Oregon		PROJECT Farm Drainage - John Doe		
BY H.J.W.	DATE 11/8/71	CHECKED BY	DATE	JOB NO.
SUBJECT Example #2 - Field Drain Design				SHEET 4 OF 5

Dayton

See W.V.D.G. page 116, and Appendix D page 197 & 198

Closed pattern drainage
drain spacing 40'-60'; depth 3.5'-5.0'

Bedding, Filter, Envelopment, and backfill
Materials Ia or IIa & IIIa
Bedding - Trench groove
filter or envelope - organic materials or graded sand & gravel

Concord

See W.V.D.G. page 114, and Appendix D page 197 & 198

Closed pattern drainage
drain spacing 60'-80' depth 3.5'-4.5'

Bedding, Filter, Envelopment, and backfill
Materials IIa & IIIc
bedding - trench groove
envelope - organic materials
backfill - trench run materials

See layout sketch on the next sheet.

COMPUTATION SHEET

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U. S. DEPARTMENT OF AGRICULTURE

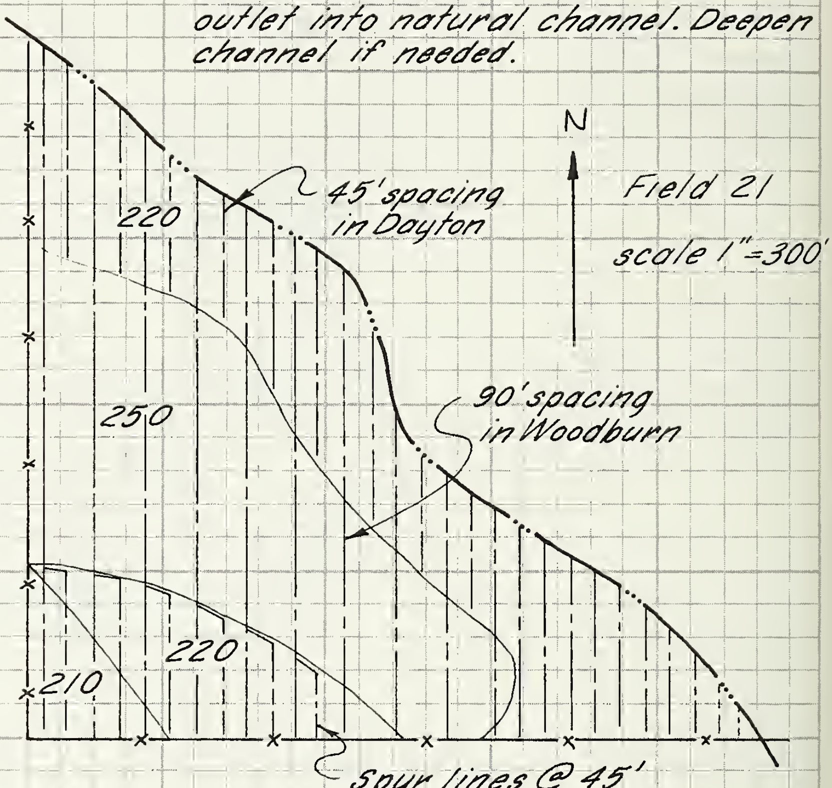
SOIL CONSERVATION SERVICE

Linn-Lane SWCD

STATE Oregon		PROJECT Farm Drainage – John Doe		
BY H.J.W.	DATE 11/9/71	CHECKED BY	DATE	JOB NO.
SUBJECT Example #2 - Field Drainage Design				SHEET 5 OF 5

FIELD DRAIN LAYOUT

outlet into natural channel. Deepen channel if needed.



Use 4" clay tile or 4" polyethylene tubing

Materials:

13,775' tile

140 c.y. Organic Envelope (chips etc.)

1, CMP 12" dia. 16' long to inlet field ditch into channel.

PART III

APPENDICES

Part III is a collection of information that can be used to aid in design of drainage systems. Appendix A contains cost estimating information which should be kept current by the user. Appendix B contains definitions of drainage terms. Appendices C and D present design information for open drains and closed drains respectively. Appendix E gives a list of SCS forms available for use in drainage work. Some standard drawings of drainage structures are shown in Appendix F.

APPENDIX A

TABLE A-1

COST ESTIMATE INFORMATION - DRAINAGE CONSTRUCTION

AVERAGE COST FOR WILLAMETTE VALLEY AREA

Costs shown in dollars/lin.ft. - Based on May 1976 prices

Item	Size of Tile or Pipe - Ins.					
	4	5	6	8	10	12
	PATTERN DRAINS					
Tile - Clay						
Tile	.18	.28	.38	.70	1.05	1.20
Trenching	.14	.14	.14	.14	.20	.20
Backfill	.02	.02	.02	.02	.02	.02
TOTAL	.34	.44	.54	.96	1.27	1.42
Tile - Concrete						
Tile	.25		.40	.74	1.00	1.15
Trenching	.14		.15	.16	.20	.20
Backfill	.02		.02	.02	.02	.02
TOTAL	.41		.57	.92	1.22	1.37
Drainage Tubing - Plastic						
Tubing	.19	.30	.44	.79		
Trenching	.14	.15	.16	.19		
Backfill	.02	.02	.02	.02		
TOTAL	.35	.48	.62	.90		
	INTERCEPTION DRAINS					
Tile or Tubing	.18	.28	.38	.70	1.05	1.20
Trenching	.20	.20	.25	.25	.25	.30
Backfill	.06	.06	.07	.07	.08	.08
TOTAL	.44	.54	.70	1.02	1.38	1.58

Table A-1 (con't.)

APPENDIX A

FILTER COSTS *

Cost shown in dollars/lin.ft. - Based on May 1976 prices

Pipe or Tile Size - Inches	Trench Width - Inches 12"	15"	18"
4"	.12		
5"	.12		
6"		.16	
8"		.18	
10"			.23
12"			.28

* Based on 6 inches of cover over tile and filter material cost of $4.00/cy.

COST OF FILTER MATERIALS

Sawdust or Barkdust	- $30.00 - $37.50/unit (7½cy);	$4.00 - $5.00/cy.
Pea Gravel	-	$3.50 - $4.50/cy.
Prepared graded sand and filter material	-	$4.00 - $10.00/cy.

Filter will cost more when wider trench widths than shown are used or if filter is carried up in trench more than 6 inches as shown in the table. Adjust unit prices accordingly.

MISCELLANEOUS COSTS ON DRAINAGE WORK

Structures	
Pipe	$12.00 - $100.00 ea
Reinforced Concrete	$75.00 - $300.00 ea
Excavation - Open Channel	
Carryall	$ 0.35/cy
Dragline	$ 0.40/cy
Backhoe	$ 0.40/cy
Bulldozer	$ 0.40/cy
Spreading Spoil Banks	
Dozer	$ 0.10/cy
Drainage Field Ditch	
Large	$ 0.40/cy
Clearing	$300.00 - $500.00/ac
Rights of Way	$200.00 - $1,500.00/ac
Drainage Land Grading	$20.00 - $80.00/ac

APPENDIX B

DRAINAGE SYSTEM TERMS

The terms used in this handbook, applying to drainage systems and to their various parts, are defined to provide Service personnel with a uniform understanding of their meaning.

Surface Drainage

Outlet - The terminal point beyond which a drainage system or ditch no longer guides nor controls the water it discharges.

Disposal system - That part of a drainage system or unit of a system used primarily to receive water from the collection system and convey it to an outlet.

Main ditch channel - The principal ditch, channel, or stream--natural, improved, or constructed--serving one or more drainage enterprises. Local names of streams, rivers, or channels should be used for identification.

Lateral - A major ditch in a drainage enterprise, usually identified by number or name. A lateral is the link between the main ditch and a sublateral or farm laterals.

Sublateral - An important branch ditch, tributary to a lateral and identified by name or number. When needed, it is the link between a lateral and farm laterals.

Farm lateral - A principal drainage ditch serving only one farm or a major portion of one farm. It is the link between field laterals and the disposal ditch or channel which usually serves a group of farms.

Field lateral - The disposal ditch serving those fields adjacent to it on one farm. It is the link between the farm lateral and the collection system.

Collection system - A drainage system or ditch which collects excess runoff water.

Field ditch - A graded collection ditch, usually shallow and having flat sides for ease of crossing, which collects water within a field. Water may enter it through crop rows or row ditches or by sheet flow over smooth field surfaces.

Rows - Crop rows are small channels developed in the preparation of cropland or in cultivating the crop. Their location and arrangement will determine their efficiency in collecting water.

APPENDIX B

Row ditch - A small plow or shovel ditch enlarged or cut across crop rows at low places each crop season to collect row water and carry it into a field ditch or field lateral. These are often called annual, quarter, header ditches, etc.

Land forming - The process of changing the surface of the land to insure the orderly movement of surface water over a field or a part of a field.

Land grading - The shaping of the land surface by grading, filling depressions and smoothing to planned grades. The primary purpose is to improve land drainage by establishing uniform grades so that runoff will flow over the surface without ponding. This practice is also called, in some locations, precision grading or land shaping.

Rough grading - The shaping of the land surface "by eye" or by limited use of engineering surveys. This operation may also be the first step in land grading.

Land smoothing - Shaping the land surface to eliminate minor differences in elevation and to smooth out depressions without changing the general contours of the land. The depth of cut in this operation is generally small and limited by the kind of equipment used. Land smoothing is also the finishing operation in land grading.

Land bedding - Plowing, blading, or otherwise elevating the surface of flatland into a series of broad, low ridges separated by shallow, parallel dead furrows or field ditches. Also known as "crowning" or "ridging" in some localities.

Land leveling - The shaping of the ground surface by grading and smoothing to a planned grade and to specification required to permit the uniform distribution of irrigation water. Land-leveling operations nearly always provide improved drainage. In some cases improved drainage may be the initial objective of land leveling and the application of irrigation water a delayed objective.

Diversion system - A ditch system, ditch, or dike which diverts water away from a lower-lying area or prevents water from flooding land.

Diversion ditch - A graded channel constructed across the land slope to intercept and divert flowing water to a suitable outlet. Its capacity may be enlarged by shaping the spoil into a continuous smooth ridge on the lower side of the ditch.

Levee or dike - An earth embankment constructed to prevent overflow of land by streams, lakes, or tidal waters.

Floodway - An area adjacent to a stream or ditch, bounded by levees, high ground, or both, on which the overflow from the stream or ditch is confined

APPENDIX B

SUBSURFACE DRAINAGE

Note: Individual subsurface drains or subsurface drainage systems should be identified as being either "open" or "closed."

Outlet - The terminal point of a subsurface system or of a subsurface drain.

Disposal system - An open or closed system or a drain needed primarily to convey the collected ground water to an outlet.

Main drain - The principal drain which conducts the drainage water from the collection (lateral) drains and submains to the outlet.

Submain drain - A branch drain off the main drain into which collection (lateral) drains discharge water.

Vertical drain - A well, pipe, pit, or bore into a porous underlying strata into which subsurface drainage water can be discharged. This is also called a drainage well.

Collection system - A system of open or closed drains where each drain is located so as to be of maximum benefit in collecting ground water, thereby lowering the ground-water table.

Note: Where only a single line subsurface drain is required, it is classed as a collection drain.

Lateral drain - A drain located so as to have maximum effect in controlling the water table. It collects water from the soil and usually discharges into a submain or main.

Relief drain - A lateral drain located parallel, or approximately so, to the flow of ground water.

Interceptor drain - An open or closed drain located across the flow of ground water (or seepage) and installed primarily for intercepting subsurface flow moving down a slope.

Relief well drain - A vertical shallow well, pit, or bore which carries water upward from a subsurface layer, under hydrostatic pressure, into an open or closed drain. An excavated relief well drain may be backfilled with pervious material or it may be lined with pipe or tile.

Pumped well drain - A well sunk into an aquifer from which water is pumped to lower the water table.

APPENDIX B

Mole drain - A closed drain, formed into an unlined conduit by pulling a bullet-shaped cylinder through the soil. The mole drain may discharge into either an open channel or closed drain.

Water control system - All or a part of a drainage system in which inflow and outflow of water can be regulated to maintain a predetermined elevation of the water table.

Water control facility - A ditch, drain, levee or dike, or a pump designed to aid in maintaining the flow of water from, through, or to an area for the purpose of controlling the elevation of the water table.

Water control structure - A structure designed to regulate the elevation of the water in a ditch or drain for the purpose of controlling the water table.

Drainage pumping plant - A pumping plant powered by electric motors or internal combustion engines. It is for the purpose of removing the excess water from an area having no gravity outlet.

APPENDIX C

DITCH SIDE SLOPES

Side slopes are determined primarily by the stability of the materials through which the ditch is dug and the methods of maintenance to be practiced. Maintenance requirements may necessitate modification. The steepest side slopes recommended for ordinary conditions for mains or laterals are as follows:

Soil	Side Slopes
Loam	2:1
Clay	1½:1
Peat, muck and sand	1:1

Experience in certain types of soil may indicate that steeper side slopes may be used. Maintenance requirements may justify flattening side slopes. Ditch side slopes which may be used with various maintenance methods are given in Table C-1.

Table C-1 Ditch side slope recommended for maintenance

Type of Maintenance	Recommended Steepest Side Slopes	Remarks
Mowing	3:1	Flatter slopes desirable
Grazing	2:1 or flatter	For ditches greater than 4 feet deep
	1½:1 or flatter	For ditches less than 4 feet deep
Dragline	½:1	Usually used on ditches with steep side slopes, greater than 4 feet deep
Blade equipment	3:1	Flatter slopes desirable
Turning plows	3:1	Flatter slopes desirable
Chemicals	Any	Use caution near crops
Burning	Any	

From Chapter 14; Engineering Field Manual for Conservation Practices; USDA,SCS.

APPENDIX C

VELOCITY IN DITCHES

The ideal velocity for a ditch is one which causes neither scouring nor sedimentation. Since flows in most ditches are intermittent, the velocity will fluctuate. Ditches are usually designed for the maximum design flow and the allowable velocity in the ditch section. Where possible, the velocity in a ditch should increase going downstream to keep the sediment moving. This is seldom possible since the grade of the ditch conforms with the slope of the land and the steep grades usually are in the upper reaches. Table C-2 contains recommended limiting velocities of design high water for various soils and materials, above which scour and erosion may take place. Raw, newly dug ditches may have a frictional value "n" less than will exist after some aging of the ditch takes place. Therefore, higher than design velocities may be expected in new ditches. When turf on the ditchside slopes is slow in developing, the limiting velocities may need to be reduced. An engineer should be consulted as to the adjustments that should be made.

Table C-2 Permissible velocities

Soil Texture	Maximum Velocity ft./sec.
Sand and sandy loam (noncolloidal)	2.5
Silt loam (also high lime clay)	3.0
Sandy clay loam	3.5
Clay loam	4.0
Stiff clay, fine gravel, graded loam to gravel	5.0
Graded silt to cobbles (colloidal)	5.5
Shale, hardpan and coarse gravel	6.0

From Chapter 14; Engineering Field Manual for Conservation Practices; USDA,SCS.

APPENDIX C

VALUE OF COEFFICIENT OF FRICTION "n"

The value of "n" is a factor in the formula for velocity. It indicates not only the roughness of the sides and bottom of the channel but also other types of irregularities of the channel, such as alignment and vegetation. The value of "n" is used to indicate the net effect of all factors causing retardation of flow. Its selection requires judgment in evaluating the factors of the material in which the channel is constructed, irregularity of surfaces of the ditch sides and bottom, variations in the shape and size of cross sections, obstructions, vegetation, and meandering of the ditch.

The National Engineering Handbook, Section 16, relates "n" values to the hydraulic radius and indicates that the "n" values decrease when the hydraulic radius increases. Table C-3 gives the values of "n" recommended for design. These are the values which may be expected after aging and the "n" value actually occurring immediately after construction will be lower than the values given in the table.

Table C-3 Value of "n" for drainage ditch design

Hydraulic Radius	"n"
Less than 2.5	0.040 - 0.045
2.5 to 4.0	.035 - .040
4.0 to 5.0	.030 - .035
More than 5.0	.025 - .030

From Chapter 14; Engineering Field Manual for Conservation Practices; USDA,SCS.

APPENDIX C

USEFUL EQUATIONS

Channel dimensions may be computed mathematically by trial and error using the following relationships:

$$V = \frac{1.486}{n} r^{2/3} s^{1/2} \qquad \text{(Manning's Equation)}$$

$$Q = AV$$

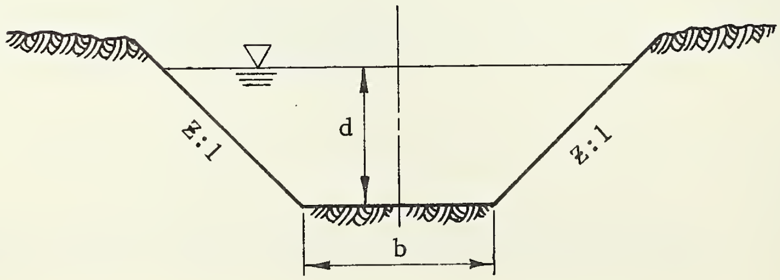
$$A = bd + zd^2$$

$$WP = b + 2\sqrt{(dz)^2 + d^2}$$

$$r = \frac{A}{WP}$$

Where

- Q = design quantity of water in cfs
- V = velocity in fps
- n = Manning's coefficient of roughness
- r = hydraulic radius in feet
- s = gradient of channel in feet per foot
- A = area in square feet
- WP = wetted perimeter
- b = bottom width in feet
- z = side slope ratio



CHANNEL DESIGN TABLES - TRIANGULAR SECTION

Z = 1.00
b = 0.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	1.39	.52	1.22	.67	1.13	.78	1.07	.87	1.03	.95	.99	1.01	.97	1.07	.94	1.13
2.00	1.80	.62	1.58	.80	1.47	.93	1.39	1.04	1.33	1.13	1.29	1.20	1.25	1.28	1.22	1.34
3.00	2.10	.68	1.84	.88	1.71	1.03	1.62	1.15	1.55	1.25	1.50	1.33	1.46	1.41	1.42	1.49
4.00	2.34	.73	2.05	.95	1.90	1.10	1.80	1.23	1.73	1.34	1.67	1.43	1.62	1.52	1.58	1.60
5.00	2.54	.77	2.23	1.00	2.07	1.17	1.96	1.30	1.88	1.41	1.82	1.51	1.77	1.61	1.72	1.69
10.00	3.30	.92	2.90	1.19	2.68	1.39	2.54	1.55	2.44	1.68	2.36	1.80	2.29	1.91	2.23	2.01
15.00	3.84	1.02	3.37	1.32	3.12	1.54	2.96	1.71	2.84	1.86	2.74	1.99	2.67	2.11	2.60	2.22
20.00	4.28	1.09	3.76	1.42	3.48	1.65	3.30	1.84	3.16	2.00	3.06	2.14	2.97	2.27	2.90	2.39
25.00	4.65	1.16	4.08	1.50	3.78	1.75	3.59	1.95	3.44	2.12	3.32	2.27	3.23	2.40	3.15	2.52
30.00	4.98	1.21	4.37	1.57	4.05	1.83	3.84	2.04	3.68	2.21	3.56	2.37	3.46	2.51	3.37	2.64
35.00	5.27	1.26	4.63	1.63	4.29	1.90	4.07	2.12	3.90	2.30	3.77	2.46	3.66	2.61	3.57	2.74
40.00	5.55	1.30	4.87	1.69	4.51	1.96	4.28	2.19	4.10	2.38	3.96	2.55	3.85	2.70	3.76	2.84
45.00	5.80	1.34	5.09	1.74	4.72	2.02	4.47	2.25	4.29	2.45	4.14	2.62	4.02	2.78	3.92	2.92
50.00	6.03	1.38	5.29	1.78	4.91	2.08	4.65	2.31	4.46	2.52	4.31	2.69	4.19	2.85	4.08	3.00
55.00	6.25	1.41	5.49	1.83	5.09	2.13	4.82	2.37	4.62	2.58	4.47	2.76	4.34	2.92	4.23	3.07
60.00	6.46	1.44	5.67	1.87	5.25	2.17	4.98	2.42	4.77	2.63	4.61	2.82	4.48	2.99	4.37	3.14
65.00	6.65	1.47	5.84	1.91	5.41	2.22	5.13	2.47	4.92	2.69	4.75	2.88	4.62	3.05	4.51	3.20
70.00	6.84	1.50	6.01	1.94	5.57	2.26	5.27	2.52	5.06	2.74	4.89	2.93	4.75	3.10	4.63	3.26
75.00	7.02	1.52	6.16	1.97	5.71	2.30	5.41	2.56	5.19	2.78	5.02	2.98	4.87	3.16	4.75	3.32
80.00	7.19	1.55	6.32	2.01	5.85	2.34	5.55	2.60	5.32	2.83	5.14	3.03	4.99	3.21	4.87	3.37
85.00	7.36	1.57	6.46	2.04	5.99	2.37	5.67	2.64	5.44	2.87	5.26	3.08	5.11	3.26	4.98	3.43
90.00	7.52	1.59	6.60	2.07	6.12	2.41	5.80	2.68	5.56	2.91	5.37	3.12	5.22	3.31	5.09	3.48
95.00	7.67	1.62	6.74	2.09	6.24	2.44	5.91	2.72	5.67	2.95	5.48	3.16	5.33	3.35	5.19	3.52
100.00	7.82	1.64	6.87	2.12	6.36	2.47	6.03	2.75	5.78	2.99	5.59	3.20	5.43	3.39	5.29	3.57

Constants - sideslope Z = 1. ; bottom width, b = 0 ft ; Mannings n = 0.040
Enter chart with discharge, Q(cfs) and channel slope, s(ft./ft.)
Find - depth, d (ft.) and Velocity, V(ft./sec.)

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

Z = 1.00
b = 2.00
n = 0.040

Q	s = .0005 d	V	s = .0010 d	V	s = .0015 d	V	s = .0020 d	V	s = .0025 d	V	s = .0030 d	V	s = .0035 d	V	s = .0040 d	V
1.00	.72	.51	.59	.66	.53	.76	.48	.83	.45	.90	.43	.96	.41	1.01	.40	1.06
2.00	1.06	.62	.87	.80	.78	.92	.72	1.03	.68	1.11	.64	1.18	.61	1.25	.59	1.31
3.00	1.31	.69	1.09	.89	.98	1.03	.90	1.15	.85	1.24	.81	1.33	.77	1.40	.74	1.47
4.00	1.52	.75	1.27	.96	1.14	1.12	1.06	1.24	.99	1.35	.94	1.44	.91	1.52	.87	1.60
5.00	1.71	.79	1.43	1.02	1.28	1.19	1.19	1.32	1.12	1.43	1.07	1.53	1.02	1.62	.99	1.70
10.00	2.41	.94	2.03	1.22	1.84	1.42	1.71	1.58	1.61	1.72	1.54	1.84	1.48	1.94	1.43	2.04
15.00	2.93	1.04	2.48	1.35	2.25	1.57	2.09	1.75	1.98	1.90	1.89	2.04	1.82	2.16	1.76	2.27
20.00	3.35	1.12	2.85	1.45	2.58	1.69	2.41	1.88	2.28	2.05	2.18	2.19	2.10	2.32	2.03	2.44
25.00	3.71	1.18	3.16	1.53	2.87	1.79	2.68	1.99	2.54	2.16	2.43	2.32	2.35	2.45	2.27	2.58
30.00	4.03	1.24	3.44	1.60	3.13	1.87	2.93	2.08	2.78	2.26	2.66	2.42	2.56	2.57	2.48	2.70
35.00	4.32	1.28	3.69	1.67	3.36	1.94	3.15	2.16	2.99	2.35	2.86	2.52	2.76	2.67	2.67	2.81
40.00	4.58	1.33	3.92	1.72	3.58	2.01	3.35	2.24	3.18	2.43	3.05	2.60	2.94	2.76	2.85	2.90
45.00	4.83	1.36	4.14	1.77	3.70	2.07	3.53	2.30	3.36	2.50	3.22	2.68	3.10	2.84	3.01	2.99
50.00	5.06	1.40	4.34	1.82	3.96	2.12	3.71	2.36	3.52	2.57	3.38	2.75	3.26	2.92	3.16	3.07
55.00	5.27	1.43	4.53	1.86	4.13	2.17	3.87	2.42	3.68	2.62	3.53	2.82	3.41	2.99	3.30	3.14
60.00	5.48	1.46	4.71	1.90	4.30	2.22	4.03	2.47	3.83	2.69	3.67	2.88	3.55	3.05	3.44	3.21
65.00	5.67	1.49	4.87	1.94	4.46	2.26	4.18	2.52	3.97	2.74	3.81	2.94	3.68	3.11	3.57	3.27
70.00	5.86	1.52	5.04	1.98	4.60	2.30	4.32	2.57	4.11	2.79	3.94	2.99	3.81	3.17	3.69	3.33
75.00	6.03	1.55	5.19	2.01	4.75	2.34	4.45	2.61	4.24	2.84	4.07	3.04	3.93	3.22	3.81	3.39
80.00	6.20	1.57	5.34	2.04	4.89	2.38	4.58	2.65	4.36	2.88	4.19	3.09	4.04	3.27	3.92	3.44
85.00	6.37	1.60	5.48	2.07	5.02	2.41	4.71	2.69	4.48	2.93	4.30	3.14	4.16	3.32	4.03	3.50
90.00	6.53	1.62	5.62	2.10	5.15	2.45	4.83	2.73	4.60	2.97	4.41	3.18	4.26	3.37	4.14	3.55
95.00	6.68	1.64	5.75	2.13	5.27	2.48	4.95	2.77	4.71	3.01	4.52	3.22	4.37	3.42	4.24	3.59
100.00	6.82	1.66	5.88	2.16	5.39	2.51	5.06	2.80	4.82	3.05	4.63	3.26	4.47	3.46	4.34	3.64

Constants - sideslope Z = 1.00 ; bottom width , b = 2.00 ft ; Mannings n = 0.040
Enter chart with discharge , Q (cfs) and channel slope , s (ft./ ft.)
Find - depth , d (ft.) and Velocity, V (ft./sec.)

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

Z = 1.00
b = 4.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.49	.46	.40	.57	.35	.65	.32	.72	.30	.77	.29	.82	.27	.86	.26	.90
2.00	.74	.57	.60	.73	.53	.83	.49	.91	.46	.98	.43	1.04	.41	1.10	.40	1.15
3.00	.93	.65	.76	.83	.68	.95	.62	1.05	.58	1.13	.55	1.20	.53	1.26	.51	1.32
4.00	1.10	.71	.90	.90	.80	1.04	.74	1.15	.69	1.24	.65	1.32	.63	1.39	.60	1.45
5.00	1.26	.76	1.03	.97	.91	1.11	.84	1.23	.79	1.33	.75	1.41	.71	1.49	.69	1.56
10.00	1.85	.92	1.53	1.19	1.36	1.37	1.26	1.52	1.18	1.64	1.12	1.75	1.07	1.85	1.03	1.94
15.00	2.31	1.03	1.91	1.33	1.71	1.54	1.52	1.71	1.40	1.80	1.41	1.97	1.35	2.08	1.30	2.18
20.00	2.69	1.11	2.24	1.44	2.00	1.66	1.85	1.85	1.74	2.00	1.65	2.14	1.59	2.26	1.53	2.37
25.00	3.02	1.18	2.52	1.52	2.26	1.77	2.09	1.96	1.97	2.13	1.87	2.28	1.79	2.41	1.73	2.53
30.00	3.32	1.24	2.77	1.60	2.49	1.86	2.31	2.06	2.17	2.24	2.07	2.39	1.98	2.53	1.91	2.66
35.00	3.59	1.29	3.01	1.66	2.70	1.93	2.51	2.15	2.36	2.33	2.25	2.49	2.16	2.64	2.08	2.77
40.00	3.84	1.33	3.22	1.72	2.90	2.00	2.69	2.23	2.54	2.42	2.42	2.58	2.32	2.73	2.24	2.87
45.00	4.07	1.37	3.42	1.77	3.08	2.06	2.86	2.29	2.70	2.49	2.57	2.66	2.47	2.82	2.38	2.96
50.00	4.29	1.41	3.61	1.82	3.25	2.12	3.01	2.35	2.85	2.56	2.72	2.74	2.61	2.90	2.52	3.05
55.00	4.49	1.44	3.79	1.87	3.42	2.17	3.17	2.42	3.00	2.63	2.86	2.81	2.74	2.97	2.65	3.12
60.00	4.69	1.47	3.95	1.91	3.57	2.22	3.32	2.47	3.13	2.69	2.99	2.87	2.87	3.04	2.77	3.20
65.00	4.88	1.50	4.11	1.95	3.72	2.27	3.46	2.52	3.27	2.74	3.12	2.93	2.99	3.11	2.89	3.26
70.00	5.05	1.53	4.27	1.98	3.86	2.31	3.59	2.57	3.39	2.79	3.24	2.99	3.11	3.17	3.01	3.33
75.00	5.22	1.56	4.42	2.02	3.99	2.35	3.72	2.62	3.51	2.84	3.35	3.04	3.22	3.22	3.11	3.39
80.00	5.39	1.58	4.56	2.05	4.12	2.39	3.84	2.66	3.63	2.89	3.47	3.09	3.33	3.28	3.22	3.44
85.00	5.55	1.61	4.69	2.08	4.25	2.43	3.96	2.70	3.74	2.94	3.57	3.14	3.44	3.33	3.32	3.50
90.00	5.70	1.63	4.83	2.11	4.37	2.46	4.07	2.74	3.85	2.98	3.68	3.19	3.54	3.38	3.42	3.55
95.00	5.85	1.65	4.93	2.14	4.49	2.49	4.18	2.78	3.96	3.02	3.78	3.23	3.64	3.42	3.52	3.60
100.00	5.99	1.67	5.08	2.17	4.60	2.53	4.29	2.81	4.06	3.06	3.88	3.27	3.73	3.47	3.61	3.64

Constants - sideslope Z = 1.00; bottom width, b = 4.00 ft.; Mannings n = 0.040
Enter chart with discharge, Q (cfs) and channel slope, s (ft./ft.)
Find — depth, d (ft.) and Velocity, V (ft./sec.)

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

Z = 1.00
b = 6.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.38	.41	.31	.51	.28	.58	.25	.63	.24	.68	.22	.72	.21	.75	.21	.79
2.00	.58	.52	.47	.66	.42	.75	.38	.82	.36	.88	.34	.93	.32	.98	.31	1.02
3.00	.74	.60	.60	.76	.53	.86	.49	.95	.46	1.02	.43	1.08	.41	1.13	.40	1.18
4.00	.88	.66	.72	.83	.63	.95	.58	1.05	.54	1.13	.52	1.19	.49	1.26	.47	1.31
5.00	1.00	.71	.82	.90	.72	1.03	.66	1.13	.62	1.22	.59	1.29	.56	1.36	.54	1.42
10.00	1.51	.89	1.23	1.13	1.09	1.29	1.00	1.43	.94	1.54	.89	1.63	.85	1.72	.82	1.80
15.00	1.90	1.00	1.56	1.28	1.38	1.47	1.27	1.62	1.19	1.75	1.13	1.86	1.08	1.96	1.04	2.05
20.00	2.24	1.09	1.84	1.39	1.64	1.60	1.51	1.77	1.41	1.91	1.34	2.04	1.28	2.15	1.23	2.25
25.00	2.53	1.16	2.09	1.48	1.86	1.71	1.71	1.89	1.61	2.05	1.52	2.18	1.46	2.30	1.40	2.41
30.00	2.80	1.22	2.31	1.56	2.06	1.80	1.90	2.00	1.78	2.16	1.69	2.31	1.62	2.43	1.56	2.55
35.00	3.05	1.27	2.52	1.63	2.25	1.89	2.07	2.09	1.95	2.26	1.85	2.41	1.77	2.55	1.70	2.67
40.00	3.28	1.32	2.71	1.69	2.43	1.96	2.24	2.17	2.10	2.35	2.00	2.51	1.91	2.65	1.84	2.78
45.00	3.49	1.36	2.90	1.75	2.59	2.02	2.39	2.25	2.25	2.43	2.13	2.60	2.04	2.74	1.97	2.88
50.00	3.70	1.40	3.07	1.80	2.74	2.08	2.53	2.31	2.38	2.51	2.26	2.68	2.17	2.83	2.09	2.96
55.00	3.89	1.43	3.23	1.85	2.89	2.14	2.67	2.38	2.51	2.57	2.39	2.75	2.29	2.90	2.20	3.05
60.00	4.07	1.46	3.39	1.89	3.03	2.19	2.80	2.43	2.64	2.64	2.51	2.82	2.40	2.98	2.31	3.12
65.00	4.24	1.50	3.53	1.93	3.17	2.24	2.93	2.49	2.76	2.70	2.62	2.88	2.51	3.04	2.42	3.19
70.00	4.41	1.52	3.68	1.97	3.30	2.28	3.05	2.54	2.87	2.75	2.73	2.94	2.62	3.11	2.52	3.26
75.00	4.57	1.55	3.81	2.00	3.42	2.33	3.17	2.58	2.98	2.80	2.84	3.00	2.72	3.17	2.62	3.32
80.00	4.73	1.58	3.95	2.04	3.54	2.37	3.28	2.63	3.09	2.85	2.94	3.05	2.82	3.22	2.71	3.38
85.00	4.88	1.60	4.07	2.07	3.66	2.41	3.39	2.67	3.19	2.90	3.04	3.10	2.91	3.28	2.81	3.44
90.00	5.02	1.63	4.20	2.10	3.77	2.44	3.49	2.71	3.29	2.95	3.13	3.15	3.00	3.33	2.90	3.50
95.00	5.16	1.65	4.32	2.13	3.88	2.48	3.60	2.75	3.39	2.99	3.23	3.19	3.09	3.38	2.98	3.55
100.00	5.30	1.67	4.44	2.16	3.99	2.51	3.70	2.79	3.48	3.03	3.32	3.24	3.18	3.43	3.07	3.60
105.00	5.43	1.69	4.55	2.19	4.09	2.54	3.79	2.83	3.57	3.07	3.40	3.28	3.27	3.47	3.15	3.65
110.00	5.56	1.71	4.66	2.22	4.19	2.57	3.89	2.86	3.66	3.11	3.49	3.32	3.35	3.52	3.23	3.69
115.00	5.69	1.73	4.77	2.24	4.29	2.60	3.98	2.90	3.75	3.14	3.57	3.36	3.43	3.56	3.31	3.74
120.00	5.81	1.75	4.87	2.27	4.39	2.63	4.07	2.93	3.84	3.18	3.66	3.40	3.51	3.60	3.39	3.78
125.00	5.93	1.77	4.98	2.29	4.48	2.66	4.16	2.96	3.92	3.21	3.74	3.44	3.59	3.64	3.46	3.82
130.00	6.05	1.79	5.08	2.31	4.57	2.69	4.24	2.99	4.00	3.25	3.82	3.47	3.66	3.68	3.53	3.86

Constants — sideslope Z = 1.00 ; bottom width , b = 6.00 ft.; Mannings n = 0.040
Enter chart with discharge , Q(cfs) and channel slope , s (ft./ ft.)
Find — depth , d (ft.) and Velocity , V(ft./sec.)

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

Z = 1.00
b = 8.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.32	.37	.26	.46	.23	.53	.21	.57	.20	.62	.19	.65	.18	.68	.17	.71
2.00	.49	.48	.40	.60	.35	.68	.32	.75	.30	.80	.29	.85	.27	.89	.26	.93
3.00	.62	.56	.51	.70	.45	.79	.41	.87	.39	.93	.36	.99	.35	1.04	.33	1.08
4.00	.74	.62	.60	.77	.53	.88	.49	.96	.46	1.04	.43	1.10	.41	1.15	.40	1.20
5.00	.85	.67	.69	.84	.61	.95	.56	1.05	.52	1.12	.50	1.19	.47	1.25	.45	1.30
10.00	1.28	.84	1.04	1.06	.92	1.22	.85	1.34	.79	1.44	.75	1.52	.72	1.60	.69	1.67
15.00	1.63	.96	1.33	1.21	1.18	1.39	1.08	1.53	1.01	1.65	.96	1.75	.91	1.84	.88	1.93
20.00	1.92	1.05	1.57	1.33	1.39	1.53	1.28	1.69	1.20	1.82	1.14	1.93	1.08	2.03	1.04	2.13
25.00	2.19	1.12	1.79	1.43	1.59	1.64	1.46	1.81	1.37	1.95	1.30	2.08	1.24	2.19	1.19	2.29
30.00	2.43	1.18	1.99	1.51	1.77	1.74	1.63	1.92	1.52	2.07	1.44	2.20	1.38	2.32	1.33	2.43
35.00	2.65	1.24	2.18	1.58	1.93	1.82	1.78	2.01	1.67	2.17	1.58	2.31	1.51	2.44	1.45	2.55
40.00	2.86	1.29	2.35	1.65	2.09	1.90	1.92	2.10	1.80	2.27	1.71	2.41	1.63	2.54	1.57	2.66
45.00	3.06	1.33	2.51	1.70	2.24	1.97	2.06	2.17	1.93	2.35	1.83	2.50	1.75	2.64	1.68	2.76
50.00	3.24	1.37	2.67	1.76	2.38	2.03	2.19	2.24	2.05	2.43	1.95	2.59	1.86	2.73	1.79	2.86
55.00	3.42	1.41	2.82	1.81	2.51	2.09	2.31	2.31	2.17	2.50	2.06	2.66	1.97	2.81	1.89	2.94
60.00	3.59	1.44	2.96	1.85	2.64	2.14	2.43	2.37	2.28	2.56	2.16	2.73	2.07	2.88	1.99	3.02
65.00	3.75	1.48	3.09	1.89	2.76	2.19	2.54	2.43	2.39	2.62	2.26	2.80	2.17	2.95	2.08	3.10
70.00	3.91	1.51	3.22	1.94	2.88	2.24	2.65	2.48	2.49	2.68	2.36	2.86	2.26	3.02	2.18	3.17
75.00	4.06	1.53	3.35	1.97	2.99	2.28	2.76	2.53	2.59	2.74	2.46	2.92	2.35	3.08	2.26	3.23
80.00	4.20	1.56	3.47	2.01	3.10	2.32	2.86	2.58	2.69	2.79	2.55	2.98	2.44	3.14	2.35	3.29
85.00	4.34	1.59	3.59	2.04	3.21	2.36	2.96	2.62	2.78	2.84	2.64	3.03	2.53	3.20	2.43	3.35
90.00	4.48	1.61	3.71	2.07	3.31	2.40	3.06	2.66	2.87	2.89	2.73	3.08	2.61	3.25	2.51	3.41
95.00	4.61	1.64	3.82	2.11	3.41	2.44	3.15	2.71	2.96	2.93	2.81	3.13	2.69	3.30	2.59	3.46
100.00	4.74	1.66	3.93	2.14	3.51	2.47	3.24	2.74	3.05	2.97	2.89	3.17	2.77	3.35	2.67	3.52
105.00	4.86	1.68	4.03	2.16	3.61	2.51	3.33	2.78	3.13	3.01	2.97	3.22	2.85	3.40	2.74	3.57
110.00	4.98	1.70	4.14	2.19	3.70	2.54	3.42	2.82	3.21	3.05	3.05	3.26	2.92	3.45	2.82	3.61
115.00	5.10	1.72	4.24	2.22	3.79	2.57	3.50	2.85	3.29	3.09	3.13	3.30	3.00	3.49	2.89	3.66
120.00	5.22	1.74	4.34	2.24	3.88	2.60	3.59	2.89	3.37	3.13	3.21	3.34	3.07	3.53	2.96	3.70
125.00	5.33	1.76	4.43	2.27	3.97	2.63	3.67	2.92	3.45	3.17	3.28	3.38	3.14	3.57	3.03	3.75
130.00	5.44	1.78	4.53	2.29	4.06	2.66	3.75	2.95	3.53	3.20	3.35	3.42	3.21	3.61	3.09	3.79
135.00	5.55	1.79	4.62	2.32	4.14	2.69	3.83	2.98	3.60	3.23	3.42	3.45	3.28	3.65	3.16	3.83
140.00	5.66	1.81	4.71	2.34	4.22	2.71	3.91	3.01	3.67	3.27	3.49	3.49	3.35	3.69	3.22	3.87
145.00	5.76	1.83	4.80	2.36	4.31	2.74	3.98	3.04	3.75	3.30	3.56	3.52	3.41	3.72	3.29	3.91
150.00	5.87	1.84	4.89	2.38	4.38	2.76	4.06	3.07	3.82	3.33	3.63	3.56	3.48	3.76	3.35	3.95

Constants — sideslope Z = 1.00 ; bottom width , b = 8.00 ft ; Mannings n = 0.040
Enter chart with discharge , Q (cfs) and channel slope , s (ft./ ft.)
Find — depth , d (ft.) and Velocity , V (ft./sec.)

CHANNEL DESIGN TABLES - TRIANGULAR SECTION

Z = 2.00
b = 0.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	1.01	.49	.89	.63	.82	.74	.78	.82	.75	.90	.72	.96	.70	1.02	.69	1.07
2.00	1.31	.58	1.15	.75	1.07	.88	1.01	.98	.97	1.06	.94	1.14	.91	1.21	.89	1.27
3.00	1.53	.64	1.34	.84	1.24	.97	1.18	1.08	1.13	1.18	1.09	1.26	1.06	1.34	1.03	1.40
4.00	1.70	.69	1.49	.90	1.38	1.04	1.31	1.16	1.26	1.27	1.22	1.35	1.18	1.44	1.15	1.51
5.00	1.85	.73	1.62	.95	1.51	1.11	1.43	1.23	1.37	1.34	1.32	1.43	1.28	1.52	1.25	1.60
10.00	2.40	.87	2.11	1.13	1.95	1.31	1.85	1.45	1.77	1.59	1.71	1.70	1.67	1.81	1.62	1.90
15.00	2.79	.96	2.45	1.25	2.27	1.45	2.15	1.62	2.06	1.76	2.00	1.89	1.94	2.00	1.89	2.10
20.00	3.11	1.03	2.73	1.34	2.53	1.56	2.40	1.74	2.30	1.89	2.22	2.03	2.16	2.15	2.11	2.26
25.00	3.38	1.09	2.97	1.42	2.75	1.65	2.61	1.84	2.50	2.00	2.42	2.14	2.35	2.27	2.29	2.39
30.00	3.62	1.15	3.18	1.49	2.95	1.73	2.79	1.93	2.68	2.09	2.59	2.24	2.51	2.38	2.45	2.50
35.00	3.84	1.19	3.37	1.54	3.12	1.80	2.96	2.00	2.84	2.18	2.74	2.33	2.66	2.47	2.60	2.60
40.00	4.03	1.23	3.54	1.60	3.28	1.86	3.11	2.07	2.98	2.25	2.88	2.41	2.80	2.55	2.73	2.68
45.00	4.21	1.27	3.70	1.64	3.43	1.91	3.25	2.13	3.12	2.32	3.01	2.48	2.93	2.63	2.85	2.76
50.00	4.38	1.30	3.85	1.69	3.57	1.96	3.38	2.19	3.24	2.38	3.13	2.55	3.04	2.70	2.97	2.84
55.00	4.54	1.33	3.99	1.73	3.70	2.01	3.50	2.24	3.36	2.44	3.25	2.61	3.16	2.76	3.08	2.91
60.00	4.69	1.36	4.12	1.77	3.82	2.06	3.62	2.29	3.47	2.49	3.36	2.67	3.26	2.83	3.18	2.97
65.00	4.84	1.39	4.25	1.80	3.94	2.10	3.73	2.34	3.58	2.54	3.46	2.72	3.36	2.88	3.28	3.03
70.00	4.97	1.42	4.37	1.84	4.05	2.14	3.84	2.38	3.68	2.59	3.55	2.77	3.45	2.94	3.37	3.09
75.00	5.10	1.44	4.48	1.87	4.15	2.17	3.94	2.42	3.77	2.63	3.65	2.82	3.54	2.99	3.46	3.14
80.00	5.23	1.46	4.59	1.90	4.26	2.21	4.03	2.46	3.87	2.68	3.74	2.87	3.63	3.04	3.54	3.19
85.00	5.35	1.49	4.70	1.93	4.35	2.24	4.13	2.50	3.96	2.72	3.82	2.91	3.71	3.08	3.62	3.24
90.00	5.47	1.51	4.80	1.95	4.45	2.28	4.21	2.53	4.04	2.76	3.91	2.95	3.79	3.13	3.70	3.29
95.00	5.58	1.53	4.90	1.98	4.54	2.31	4.30	2.57	4.12	2.79	3.99	2.99	3.87	3.17	3.78	3.33
100.00	5.69	1.55	4.99	2.01	4.63	2.34	4.38	2.60	4.20	2.83	4.06	3.03	3.95	3.21	3.85	3.38

Constants - sideslope Z = 2.00, bottom width, b = 0 ft, Mannings n = 0.040
Enter chart with discharge, Q (cfs) and channel slope, s (ft./ft.)
Find - depth, d (ft.) and Velocity, V (ft./sec.)

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

Z = 2.00
b = 2.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.64	.48	.54	.61	.48	.70	.44	.78	.42	.84	.40	.90	.38	.95	.37	1.00
2.00	.91	.57	.77	.74	.69	.86	.64	.95	.61	1.03	.58	1.10	.55	1.16	.54	1.22
3.00	1.11	.64	.94	.82	.85	.96	.79	1.06	.75	1.15	.71	1.23	.69	1.30	.66	1.37
4.00	1.28	.69	1.08	.89	.98	1.03	.91	1.15	.86	1.25	.83	1.33	.79	1.41	.77	1.48
5.00	1.42	.73	1.20	.94	1.09	1.09	1.02	1.22	.96	1.32	.92	1.41	.89	1.50	.86	1.57
10.00	1.95	.87	1.67	1.13	1.52	1.31	1.42	1.46	1.35	1.58	1.29	1.70	1.24	1.79	1.20	1.89
15.00	2.33	.96	2.00	1.25	1.83	1.45	1.71	1.62	1.63	1.76	1.56	1.88	1.50	1.99	1.46	2.09
20.00	2.65	1.04	2.27	1.34	2.08	1.56	1.95	1.74	1.85	1.89	1.78	2.02	1.72	2.14	1.67	2.25
25.00	2.91	1.10	2.51	1.42	2.29	1.65	2.15	1.84	2.05	2.00	1.97	2.14	1.90	2.27	1.84	2.39
30.00	3.15	1.15	2.71	1.49	2.49	1.73	2.33	1.93	2.22	2.10	2.13	2.24	2.06	2.38	2.00	2.50
35.00	3.36	1.19	2.90	1.55	2.66	1.80	2.50	2.01	2.38	2.18	2.28	2.33	2.21	2.47	2.14	2.60
40.00	3.56	1.23	3.07	1.60	2.82	1.86	2.65	2.07	2.52	2.25	2.42	2.41	2.34	2.56	2.27	2.69
45.00	3.74	1.27	3.23	1.65	2.96	1.92	2.78	2.14	2.65	2.32	2.55	2.49	2.47	2.63	2.40	2.77
50.00	3.91	1.30	3.38	1.69	3.10	1.97	2.91	2.19	2.78	2.38	2.67	2.55	2.58	2.71	2.51	2.84
55.00	4.06	1.34	3.52	1.73	3.23	2.02	3.04	2.25	2.89	2.44	2.78	2.62	2.69	2.77	2.61	2.91
60.00	4.21	1.37	3.65	1.77	3.35	2.06	3.15	2.30	3.00	2.50	2.89	2.67	2.79	2.83	2.71	2.98
65.00	4.36	1.39	3.77	1.81	3.46	2.10	3.26	2.34	3.11	2.55	2.99	2.73	2.89	2.89	2.81	3.04
70.00	4.49	1.42	3.89	1.84	3.57	2.14	3.36	2.39	3.21	2.59	3.09	2.78	2.99	2.94	2.90	3.09
75.00	4.62	1.44	4.00	1.87	3.68	2.18	3.46	2.43	3.30	2.64	3.18	2.83	3.07	2.99	2.99	3.15
80.00	4.75	1.47	4.11	1.90	3.78	2.22	3.56	2.47	3.39	2.68	3.27	2.87	3.16	3.04	3.07	3.20
85.00	4.87	1.49	4.22	1.93	3.88	2.25	3.65	2.51	3.48	2.72	3.35	2.92	3.24	3.09	3.15	3.25
90.00	4.98	1.51	4.32	1.96	3.97	2.28	3.74	2.54	3.57	2.76	3.43	2.96	3.32	3.13	3.23	3.30
95.00	5.09	1.53	4.42	1.99	4.06	2.31	3.82	2.58	3.65	2.80	3.51	3.00	3.40	3.18	3.30	3.34
100.00	5.20	1.55	4.51	2.01	4.15	2.34	3.91	2.61	3.73	2.84	3.59	3.04	3.47	3.22	3.38	3.38

Constants - sideslope Z = 2.00 ; bottom width , b = 2.00 ft ; Mannings n = 0.040
Enter chart with discharge , Q (cfs) and channel slope , s (ft./ft.)
Find - depth , d (ft.) and Velocity , V (ft./sec.)

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

Z = 2.00
b = 4.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.47	.43	.38	.55	.34	.63	.31	.69	.29	.74	.28	.79	.27	.83	.26	.87
2.00	.69	.54	.57	.69	.51	.79	.47	.87	.44	.94	.42	1.00	.40	1.05	.38	1.10
3.00	.86	.61	.71	.78	.64	.89	.59	.99	.55	1.07	.52	1.14	.50	1.20	.48	1.25
4.00	1.01	.66	.83	.85	.75	.98	.69	1.08	.65	1.17	.62	1.24	.59	1.31	.57	1.37
5.00	1.13	.71	.94	.90	.84	1.04	.78	1.15	.73	1.25	.70	1.33	.67	1.40	.64	1.47
10.00	1.62	.85	1.36	1.10	1.22	1.27	1.13	1.41	1.07	1.53	1.02	1.63	.98	1.72	.94	1.81
15.00	1.98	.95	1.67	1.23	1.51	1.42	1.40	1.58	1.32	1.71	1.26	1.83	1.21	1.93	1.17	2.03
20.00	2.28	1.03	1.92	1.33	1.74	1.54	1.62	1.71	1.53	1.85	1.46	1.98	1.40	2.09	1.36	2.20
25.00	2.54	1.09	2.15	1.41	1.94	1.63	1.81	1.81	1.71	1.97	1.64	2.10	1.57	2.23	1.52	2.34
30.00	2.76	1.14	2.34	1.47	2.13	1.71	1.98	1.90	1.88	2.07	1.79	2.21	1.72	2.34	1.67	2.45
35.00	2.97	1.19	2.52	1.53	2.29	1.78	2.14	1.98	2.02	2.15	1.93	2.30	1.86	2.44	1.80	2.56
40.00	3.16	1.23	2.69	1.59	2.44	1.85	2.28	2.05	2.16	2.23	2.07	2.38	1.99	2.52	1.92	2.65
45.00	3.33	1.27	2.84	1.64	2.58	1.90	2.41	2.12	2.29	2.30	2.19	2.46	2.11	2.60	2.04	2.73
50.00	3.50	1.30	2.98	1.68	2.71	1.96	2.54	2.18	2.40	2.36	2.30	2.53	2.22	2.68	2.15	2.81
55.00	3.65	1.33	3.12	1.72	2.84	2.00	2.65	2.23	2.52	2.42	2.41	2.59	2.32	2.74	2.25	2.88
60.00	3.80	1.36	3.25	1.76	2.96	2.05	2.76	2.28	2.62	2.48	2.51	2.65	2.42	2.81	2.34	2.95
65.00	3.94	1.39	3.37	1.80	3.07	2.09	2.87	2.33	2.72	2.53	2.61	2.71	2.51	2.87	2.44	3.01
70.00	4.07	1.42	3.48	1.83	3.17	2.13	2.97	2.37	2.82	2.58	2.70	2.76	2.60	2.92	2.52	3.07
75.00	4.20	1.44	3.59	1.87	3.28	2.17	3.07	2.42	2.91	2.62	2.79	2.81	2.69	2.97	2.61	3.12
80.00	4.32	1.47	3.70	1.90	3.37	2.21	3.16	2.46	3.00	2.67	2.88	2.86	2.77	3.02	2.69	3.18
85.00	4.44	1.49	3.80	1.93	3.47	2.24	3.25	2.49	3.09	2.71	2.96	2.90	2.85	3.07	2.77	3.23
90.00	4.55	1.51	3.90	1.96	3.56	2.27	3.33	2.53	3.17	2.75	3.04	2.94	2.92	3.12	2.84	3.28
95.00	4.66	1.53	4.00	1.98	3.65	2.31	3.42	2.57	3.25	2.79	3.11	2.98	3.00	3.16	2.91	3.32
100.00	4.77	1.55	4.09	2.01	3.73	2.34	3.50	2.60	3.32	2.83	3.19	3.02	3.08	3.20	2.98	3.37

Constants — sideslope Z = 2.00 ; bottom width , b = 4.00 ft ; Mannings n = 0.040
Enter chart with discharge , Q (cfs) and channel slope , s (ft./ft.)
Find — depth , d (ft.) and Velocity , V (ft./sec.)

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

Z = 2.00
b = 6.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.38	.40	.31	.50	.27	.56	.25	.62	.23	.66	.22	.70	.21	.74	.20	.77
2.00	.56	.50	.46	.63	.41	.72	.38	.79	.35	.85	.33	.90	.32	.95	.31	.99
3.00	.71	.57	.58	.72	.52	.83	.48	.91	.45	.98	.42	1.04	.40	1.09	.39	1.14
4.00	.83	.63	.68	.79	.61	.91	.56	1.00	.53	1.08	.50	1.15	.48	1.21	.46	1.26
5.00	.94	.67	.78	.85	.69	.98	.64	1.08	.60	1.16	.57	1.24	.54	1.30	.52	1.36
10.00	1.38	.83	1.14	1.06	1.02	1.22	.94	1.35	.89	1.45	.84	1.55	.81	1.63	.78	1.71
15.00	1.71	.93	1.43	1.19	1.28	1.37	1.18	1.52	1.11	1.64	1.06	1.75	1.01	1.85	.98	1.94
20.00	1.99	1.01	1.66	1.29	1.49	1.49	1.38	1.65	1.30	1.79	1.24	1.91	1.19	2.02	1.14	2.11
25.00	2.23	1.07	1.87	1.38	1.68	1.59	1.56	1.76	1.47	1.91	1.40	2.04	1.34	2.15	1.29	2.26
30.00	2.45	1.12	2.05	1.45	1.85	1.68	1.71	1.86	1.62	2.01	1.54	2.15	1.48	2.27	1.43	2.38
35.00	2.65	1.17	2.22	1.51	2.00	1.75	1.86	1.94	1.75	2.10	1.67	2.24	1.60	2.37	1.55	2.49
40.00	2.83	1.21	2.38	1.57	2.14	1.81	1.99	2.01	1.88	2.18	1.79	2.33	1.72	2.46	1.66	2.58
45.00	3.00	1.25	2.52	1.62	2.28	1.87	2.12	2.08	2.00	2.25	1.91	2.41	1.83	2.55	1.77	2.67
50.00	3.15	1.29	2.66	1.66	2.40	1.93	2.23	2.14	2.11	2.32	2.01	2.48	1.93	2.62	1.87	2.75
55.00	3.30	1.32	2.79	1.70	2.52	1.98	2.34	2.20	2.22	2.38	2.11	2.55	2.03	2.69	1.96	2.83
60.00	3.45	1.35	2.91	1.74	2.63	2.02	2.45	2.25	2.32	2.44	2.21	2.61	2.13	2.76	2.05	2.89
65.00	3.58	1.38	3.03	1.78	2.74	2.07	2.55	2.30	2.41	2.49	2.30	2.66	2.21	2.82	2.14	2.96
70.00	3.71	1.41	3.14	1.82	2.84	2.11	2.65	2.34	2.50	2.54	2.39	2.72	2.30	2.87	2.22	3.02
75.00	3.83	1.43	3.25	1.85	2.94	2.15	2.74	2.39	2.59	2.59	2.48	2.77	2.38	2.93	2.30	3.08
80.00	3.95	1.46	3.35	1.88	3.04	2.19	2.83	2.43	2.68	2.64	2.56	2.82	2.46	2.98	2.38	3.13
85.00	4.07	1.48	3.45	1.91	3.13	2.22	2.91	2.47	2.76	2.68	2.64	2.86	2.54	3.03	2.45	3.18
90.00	4.18	1.50	3.54	1.94	3.21	2.25	3.00	2.51	2.84	2.72	2.71	2.91	2.61	3.08	2.52	3.23
95.00	4.28	1.52	3.64	1.97	3.30	2.29	3.08	2.54	2.91	2.76	2.78	2.95	2.68	3.12	2.59	3.28
100.00	4.39	1.54	3.73	1.99	3.38	2.32	3.15	2.58	2.99	2.80	2.86	2.99	2.75	3.16	2.66	3.32
105.00	4.49	1.56	3.82	2.02	3.46	2.35	3.23	2.61	3.06	2.83	2.93	3.03	2.82	3.21	2.73	3.37
110.00	4.59	1.58	3.90	2.04	3.54	2.38	3.30	2.64	3.13	2.87	2.99	3.07	2.88	3.25	2.79	3.41
115.00	4.68	1.60	3.98	2.07	3.62	2.40	3.38	2.67	3.20	2.90	3.06	3.10	2.95	3.28	2.85	3.45
120.00	4.78	1.62	4.06	2.09	3.69	2.43	3.45	2.70	3.27	2.93	3.12	3.14	3.01	3.32	2.91	3.49
125.00	4.87	1.63	4.14	2.11	3.76	2.46	3.51	2.73	3.33	2.97	3.19	3.17	3.07	3.36	2.97	3.53
130.00	4.95	1.65	4.22	2.13	3.83	2.48	3.58	2.76	3.39	3.00	3.25	3.21	3.13	3.39	3.03	3.56

Constants — sideslope Z = 2.00 ; bottom width , b = 6.00 ft ; Mannings n = 0.040
Enter chart with discharge , Q (cfs) and channel slope , s (ft./ ft.)
Find — depth , d (ft.) and Velocity , V(ft./ sec.)

Z = 2.00
b = 8.00
n = 0.040

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.32	.37	.26	.45	.23	.52	.21	.57	.20	.61	.19	.64	.18	.67	.17	.70
2.00	.48	.47	.39	.58	.35	.67	.32	.73	.30	.78	.28	.83	.27	.87	.26	.91
3.00	.61	.54	.50	.68	.44	.77	.40	.85	.38	.91	.36	.96	.34	1.01	.33	1.05
4.00	.72	.59	.59	.75	.52	.85	.48	.94	.45	1.01	.43	1.07	.41	1.12	.39	1.17
5.00	.81	.64	.67	.80	.59	.92	.55	1.01	.51	1.09	.48	1.15	.46	1.21	.45	1.27
10.00	1.21	.80	.99	1.01	.88	1.16	.81	1.28	.76	1.38	.73	1.46	.69	1.54	.67	1.61
15.00	1.51	.90	1.25	1.15	1.11	1.32	1.03	1.45	.96	1.57	.92	1.67	.88	1.76	.84	1.84
20.00	1.77	.98	1.46	1.25	1.31	1.44	1.21	1.59	1.13	1.72	1.08	1.83	1.03	1.93	.99	2.02
25.00	1.99	1.05	1.65	1.34	1.48	1.54	1.37	1.71	1.29	1.84	1.22	1.96	1.17	2.07	1.13	2.17
30.00	2.20	1.10	1.83	1.41	1.64	1.63	1.51	1.80	1.42	1.95	1.35	2.08	1.30	2.19	1.25	2.29
35.00	2.38	1.15	1.98	1.48	1.78	1.70	1.65	1.89	1.55	2.04	1.47	2.17	1.41	2.30	1.36	2.40
40.00	2.56	1.19	2.13	1.53	1.91	1.77	1.77	1.96	1.67	2.12	1.58	2.26	1.52	2.39	1.46	2.50
45.00	2.72	1.23	2.27	1.58	2.04	1.83	1.89	2.03	1.78	2.20	1.69	2.34	1.62	2.47	1.56	2.59
50.00	2.87	1.27	2.40	1.63	2.15	1.89	1.99	2.09	1.88	2.26	1.79	2.42	1.72	2.55	1.65	2.67
55.00	3.01	1.30	2.52	1.68	2.26	1.94	2.10	2.15	1.99	2.33	1.88	2.48	1.81	2.62	1.74	2.75
60.00	3.15	1.34	2.63	1.72	2.37	1.99	2.20	2.20	2.07	2.39	1.97	2.55	1.89	2.69	1.83	2.82
65.00	3.28	1.36	2.75	1.76	2.47	2.03	2.29	2.25	2.16	2.44	2.06	2.61	1.98	2.75	1.91	2.89
70.00	3.40	1.39	2.85	1.79	2.57	2.07	2.38	2.30	2.25	2.49	2.14	2.66	2.06	2.81	1.98	2.95
75.00	3.52	1.42	2.96	1.83	2.66	2.11	2.47	2.35	2.33	2.54	2.22	2.71	2.13	2.87	2.06	3.01
80.00	3.63	1.44	3.05	1.86	2.75	2.15	2.56	2.39	2.41	2.59	2.30	2.76	2.21	2.92	2.13	3.07
85.00	3.75	1.47	3.15	1.89	2.84	2.19	2.64	2.43	2.49	2.63	2.37	2.81	2.28	2.97	2.20	3.12
90.00	3.85	1.49	3.24	1.92	2.92	2.22	2.72	2.47	2.56	2.69	2.45	2.86	2.35	3.02	2.27	3.17
95.00	3.96	1.51	3.33	1.95	3.01	2.26	2.79	2.50	2.64	2.72	2.51	2.90	2.42	3.07	2.33	3.22
100.00	4.06	1.53	3.42	1.97	3.09	2.29	2.87	2.54	2.71	2.75	2.58	2.94	2.48	3.11	2.40	3.26
105.00	4.15	1.55	3.50	2.00	3.16	2.32	2.94	2.57	2.78	2.79	2.65	2.98	2.55	3.15	2.46	3.31
110.00	4.25	1.57	3.58	2.02	3.24	2.35	3.01	2.61	2.84	2.83	2.71	3.02	2.61	3.19	2.52	3.35
115.00	4.34	1.59	3.66	2.05	3.31	2.38	3.08	2.64	2.91	2.86	2.78	3.06	2.67	3.23	2.58	3.39
120.00	4.43	1.61	3.74	2.07	3.38	2.40	3.15	2.67	2.97	2.90	2.84	3.09	2.73	3.27	2.63	3.43
125.00	4.52	1.62	3.82	2.09	3.45	2.43	3.21	2.70	3.04	2.93	2.90	3.13	2.79	3.31	2.69	3.47
130.00	4.61	1.64	3.89	2.12	3.52	2.46	3.28	2.73	3.10	2.96	2.96	3.16	2.84	3.34	2.75	3.51
135.00	4.69	1.66	3.97	2.14	3.59	2.48	3.34	2.76	3.16	2.99	3.01	3.20	2.90	3.38	2.80	3.55
140.00	4.77	1.67	4.04	2.16	3.65	2.51	3.40	2.78	3.21	3.02	3.07	3.23	2.95	3.41	2.85	3.58
145.00	4.86	1.69	4.11	2.18	3.72	2.53	3.46	2.81	3.27	3.05	3.12	3.26	3.00	3.45	2.90	3.62
150.00	4.93	1.70	4.18	2.20	3.78	2.55	3.52	2.84	3.33	3.08	3.18	3.29	3.06	3.48	2.96	3.65

Constants — sideslope Z = 2.00 ; bottom width , b = 8.00 ft ; Mannings n = 0.040
Enter chart with discharge , Q (cfs) and channel slope , s (ft./ ft.)
Find — depth , d (ft.) and Velocity , V (ft./sec.)

CHANNEL DESIGN TABLES - TRIANGULAR SECTION

Z = 3.00
b = 0.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.86	.46	.75	.59	.70	.69	.66	.77	.63	.83	.61	.89	.60	.95	.58	.99
2.00	1.11	.54	.98	.70	.90	.82	.86	.91	.82	.99	.79	1.06	.77	1.12	.75	1.18
3.00	1.29	.60	1.14	.78	1.05	.91	1.00	1.01	.96	1.10	.92	1.17	.90	1.24	.88	1.31
4.00	1.44	.64	1.26	.84	1.17	.97	1.11	1.08	1.07	1.18	1.03	1.26	1.00	1.34	.98	1.41
5.00	1.57	.68	1.37	.88	1.27	1.03	1.21	1.15	1.16	1.25	1.12	1.33	1.09	1.41	1.06	1.49
10.00	2.03	.81	1.78	1.05	1.65	1.22	1.57	1.36	1.50	1.48	1.45	1.59	1.41	1.68	1.37	1.77
15.00	2.36	.90	2.08	1.16	1.92	1.35	1.82	1.51	1.75	1.64	1.69	1.76	1.64	1.86	1.60	1.95
20.00	2.63	.96	2.31	1.25	2.14	1.45	2.03	1.62	1.95	1.76	1.88	1.89	1.83	2.00	1.78	2.10
25.00	2.86	1.02	2.51	1.32	2.33	1.54	2.21	1.71	2.12	1.86	2.05	1.99	1.99	2.11	1.94	2.22
30.00	3.06	1.07	2.69	1.38	2.49	1.61	2.36	1.79	2.27	1.95	2.19	2.09	2.13	2.21	2.08	2.32
35.00	3.25	1.11	2.85	1.44	2.64	1.67	2.50	1.86	2.40	2.03	2.32	2.17	2.25	2.30	2.20	2.42
40.00	3.41	1.15	3.00	1.49	2.78	1.73	2.63	1.93	2.52	2.09	2.44	2.24	2.37	2.38	2.31	2.50
45.00	3.57	1.18	3.13	1.53	2.90	1.78	2.75	1.98	2.64	2.16	2.55	2.31	2.48	2.45	2.42	2.57
50.00	3.71	1.21	3.26	1.57	3.02	1.83	2.86	2.04	2.74	2.21	2.65	2.37	2.58	2.51	2.51	2.64
55.00	3.85	1.24	3.38	1.61	3.13	1.87	2.97	2.09	2.84	2.27	2.75	2.43	2.67	2.57	2.60	2.70
60.00	3.97	1.27	3.49	1.64	3.23	1.91	3.06	2.13	2.94	2.32	2.84	2.48	2.76	2.63	2.69	2.76
65.00	4.09	1.29	3.60	1.68	3.33	1.95	3.16	2.17	3.03	2.36	2.93	2.53	2.84	2.68	2.77	2.82
70.00	4.21	1.32	3.70	1.71	3.43	1.99	3.25	2.22	3.11	2.41	3.01	2.58	2.92	2.73	2.85	2.87
75.00	4.32	1.34	3.79	1.74	3.52	2.02	3.33	2.25	3.20	2.45	3.09	2.62	3.00	2.78	2.93	2.92
80.00	4.43	1.36	3.89	1.77	3.60	2.06	3.41	2.29	3.27	2.49	3.16	2.67	3.07	2.83	3.00	2.97
85.00	4.53	1.38	3.98	1.79	3.69	2.09	3.49	2.33	3.35	2.53	3.24	2.71	3.14	2.87	3.07	3.02
90.00	4.63	1.40	4.06	1.82	3.76	2.12	3.57	2.36	3.42	2.57	3.31	2.75	3.21	2.91	3.13	3.06
95.00	4.72	1.42	4.15	1.84	3.84	2.15	3.64	2.39	3.49	2.60	3.37	2.78	3.28	2.95	3.20	3.10
100.00	4.81	1.44	4.23	1.87	3.92	2.17	3.71	2.42	3.56	2.63	3.44	2.82	3.34	2.99	3.26	3.14

Constants - sideslope Z = 3.00 ; battam width , b = 0 ft ; Mannings n =0.040
Enter chart with discharge , Q (cfs) and channel slope , s (ft./ft.)
Find - depth , d (ft.) and Velacity , V (ft./sec.)

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

Z = 3.00
b = 2.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.60	.44	.50	.57	.45	.66	.42	.73	.40	.80	.38	.85	.36	.90	.35	.94
2.00	.83	.53	.71	.69	.64	.80	.60	.89	.56	.96	.54	1.03	.52	1.09	.50	1.14
3.00	1.01	.59	.86	.77	.78	.89	.73	.99	.69	1.07	.66	1.15	.63	1.22	.61	1.28
4.00	1.15	.64	.98	.83	.89	.96	.83	1.07	.79	1.16	.76	1.24	.73	1.31	.71	1.38
5.00	1.27	.68	1.09	.88	.99	1.02	.93	1.13	.88	1.23	.84	1.32	.81	1.39	.79	1.46
10.00	1.73	.81	1.48	1.05	1.36	1.22	1.27	1.35	1.21	1.47	1.16	1.57	1.12	1.67	1.09	1.75
15.00	2.05	.90	1.77	1.16	1.62	1.35	1.52	1.50	1.45	1.63	1.39	1.75	1.35	1.85	1.31	1.94
20.00	2.32	.96	2.00	1.25	1.84	1.45	1.73	1.62	1.64	1.76	1.58	1.88	1.53	1.99	1.48	2.09
25.00	2.55	1.02	2.20	1.32	2.02	1.54	1.90	1.71	1.81	1.86	1.74	1.99	1.68	2.11	1.64	2.21
30.00	2.75	1.07	2.38	1.38	2.18	1.61	2.05	1.79	1.96	1.95	1.88	2.08	1.82	2.21	1.77	2.32
35.00	2.93	1.11	2.54	1.44	2.33	1.67	2.19	1.86	2.09	2.02	2.01	2.17	1.95	2.29	1.89	2.41
40.00	3.10	1.15	2.68	1.48	2.47	1.73	2.32	1.92	2.21	2.09	2.13	2.24	2.06	2.37	2.00	2.49
45.00	3.25	1.18	2.82	1.53	2.59	1.78	2.44	1.98	2.33	2.16	2.24	2.31	2.17	2.44	2.11	2.57
50.00	3.39	1.21	2.94	1.57	2.71	1.83	2.55	2.04	2.43	2.21	2.34	2.37	2.27	2.51	2.20	2.64
55.00	3.53	1.24	3.06	1.61	2.81	1.87	2.65	2.09	2.53	2.27	2.44	2.43	2.36	2.57	2.29	2.70
60.00	3.65	1.27	3.17	1.64	2.92	1.91	2.75	2.13	2.62	2.32	2.53	2.48	2.45	2.63	2.38	2.76
65.00	3.77	1.29	3.28	1.68	3.02	1.95	2.84	2.17	2.71	2.36	2.61	2.53	2.53	2.68	2.46	2.82
70.00	3.89	1.32	3.38	1.71	3.11	1.99	2.93	2.22	2.80	2.41	2.69	2.58	2.61	2.73	2.54	2.87
75.00	4.00	1.34	3.47	1.74	3.20	2.02	3.01	2.25	2.88	2.45	2.77	2.62	2.69	2.78	2.61	2.92
80.00	4.10	1.36	3.57	1.77	3.28	2.06	3.10	2.29	2.96	2.49	2.85	2.67	2.76	2.83	2.68	2.97
85.00	4.21	1.38	3.66	1.79	3.37	2.09	3.17	2.33	3.03	2.53	2.92	2.71	2.83	2.87	2.75	3.02
90.00	4.30	1.40	3.74	1.82	3.45	2.12	3.25	2.36	3.10	2.57	2.99	2.75	2.90	2.91	2.82	3.06
95.00	4.40	1.42	3.82	1.84	3.52	2.15	3.32	2.39	3.17	2.60	3.06	2.78	2.96	2.95	2.88	3.10
100.00	4.49	1.44	3.90	1.87	3.60	2.17	3.39	2.42	3.24	2.63	3.12	2.82	3.02	2.99	2.94	3.14

Constants – sideslope Z = 3.00 ; bottom width, b = 2.00 ft ; Mannings n = 0.040
Enter chart with discharge, Q (cfs) and channel slope, s(ft./ft.)
Find – depth, d (ft.) and Velocity, V(ft./sec.)

CHANNEL DESIGN TABLES – TRAPEZOIDAL SECTION

Z = 3.00
b = 4.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.45	.41	.37	.53	.33	.60	.31	.67	.29	.72	.27	.76	.26	.80	.25	.84
2.00	.66	.51	.55	.65	.49	.75	.45	.83	.42	.90	.40	.95	.39	1.00	.37	1.05
3.00	.81	.57	.68	.73	.61	.85	.66	.94	.53	1.01	.51	1.08	.48	1.14	.47	1.19
4.00	.94	.62	.79	.80	.71	.92	.66	1.02	.62	1.10	.59	1.18	.57	1.24	.55	1.30
5.00	1.06	.66	.89	.85	.80	.98	.74	1.09	.70	1.18	.67	1.26	.64	1.33	.62	1.39
10.00	1.49	.80	1.26	1.03	1.14	1.19	1.06	1.32	1.00	1.43	.95	1.53	.92	1.62	.89	1.70
15.00	1.80	.89	1.53	1.14	1.39	1.33	1.29	1.47	1.22	1.60	1.17	1.71	1.13	1.81	1.09	1.90
20.00	2.06	.95	1.75	1.23	1.59	1.43	1.49	1.59	1.41	1.73	1.35	1.85	1.30	1.95	1.26	2.05
25.00	2.28	1.01	1.95	1.31	1.77	1.52	1.65	1.69	1.57	1.83	1.50	1.96	1.45	2.07	1.40	2.18
30.00	2.48	1.06	2.12	1.37	1.93	1.59	1.80	1.77	1.71	1.92	1.64	2.06	1.58	2.18	1.53	2.29
35.00	2.66	1.10	2.27	1.43	2.07	1.66	1.94	1.84	1.84	2.00	1.76	2.14	1.70	2.27	1.65	2.38
40.00	2.82	1.14	2.41	1.48	2.20	1.72	2.06	1.91	1.96	2.07	1.88	2.22	1.81	2.35	1.75	2.47
45.00	2.97	1.18	2.54	1.52	2.32	1.77	2.17	1.97	2.07	2.14	1.98	2.29	1.91	2.42	1.85	2.54
50.00	3.11	1.21	2.67	1.56	2.44	1.82	2.28	2.02	2.17	2.20	2.08	2.35	2.01	2.49	1.95	2.61
55.00	3.24	1.24	2.78	1.60	2.54	1.86	2.38	2.07	2.27	2.25	2.17	2.41	2.10	2.55	2.03	2.68
60.00	3.37	1.26	2.89	1.64	2.64	1.90	2.48	2.12	2.36	2.30	2.26	2.46	2.18	2.61	2.12	2.74
65.00	3.49	1.29	3.00	1.67	2.74	1.94	2.57	2.16	2.44	2.35	2.34	2.51	2.26	2.66	2.20	2.80
70.00	3.60	1.31	3.10	1.70	2.83	1.98	2.66	2.20	2.53	2.40	2.42	2.56	2.34	2.71	2.27	2.85
75.00	3.71	1.34	3.19	1.73	2.92	2.02	2.74	2.24	2.61	2.44	2.50	2.61	2.42	2.76	2.34	2.90
80.00	3.81	1.36	3.28	1.76	3.00	2.05	2.82	2.28	2.68	2.48	2.57	2.65	2.49	2.81	2.41	2.95
85.00	3.91	1.38	3.37	1.79	3.08	2.08	2.90	2.32	2.76	2.52	2.65	2.69	2.56	2.85	2.48	3.00
90.00	4.01	1.40	3.45	1.81	3.16	2.11	2.97	2.35	2.83	2.55	2.71	2.73	2.62	2.89	2.54	3.04
95.00	4.10	1.42	3.54	1.84	3.24	2.14	3.04	2.38	2.89	2.59	2.78	2.77	2.69	2.94	2.61	3.08
100.00	4.19	1.44	3.62	1.86	3.31	2.17	3.11	2.41	2.96	2.62	2.84	2.81	2.75	2.97	2.67	3.12

Constants — sideslope Z = 3.00 ; bottom width , b = 4.00 ft ; Mannings n = 0.040
Enter chart with discharge , Q (cfs) and channel slope , s (ft./ ft.)
Find — depth , d (ft.) and Velocity , V (ft./sec.)

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

Z = 3.00
b = 6.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.37	.38	.30	.48	.27	.55	.25	.60	.23	.65	.22	.69	.21	.72	.20	.76
2.00	.55	.48	.45	.61	.40	.70	.37	.77	.35	.83	.33	.88	.31	.92	.30	.96
3.00	.68	.55	.56	.69	.50	.80	.46	.88	.44	.95	.41	1.01	.40	1.06	.38	1.11
4.00	.80	.60	.66	.76	.59	.87	.55	.96	.51	1.04	.49	1.10	.47	1.16	.45	1.22
5.00	.90	.64	.75	.81	.67	.93	.62	1.03	.58	1.11	.55	1.19	.53	1.25	.51	1.31
10.00	1.30	.78	1.09	1.00	.98	1.15	.90	1.27	.85	1.38	.81	1.47	.78	1.55	.75	1.62
15.00	1.60	.87	1.34	1.12	1.21	1.29	1.12	1.43	1.06	1.55	1.01	1.66	.97	1.75	.93	1.83
20.00	1.85	.94	1.55	1.21	1.40	1.40	1.30	1.55	1.23	1.68	1.17	1.80	1.12	1.90	1.09	1.99
25.00	2.06	1.00	1.74	1.29	1.57	1.49	1.46	1.65	1.38	1.79	1.31	1.91	1.26	2.02	1.22	2.12
30.00	2.25	1.05	1.90	1.35	1.72	1.57	1.60	1.74	1.51	1.89	1.44	2.01	1.39	2.13	1.34	2.23
35.00	2.42	1.09	2.05	1.41	1.85	1.63	1.73	1.81	1.63	1.97	1.56	2.10	1.50	2.22	1.45	2.33
40.00	2.58	1.13	2.19	1.46	1.98	1.69	1.85	1.88	1.75	2.04	1.67	2.18	1.61	2.31	1.55	2.42
45.00	2.73	1.17	2.31	1.51	2.10	1.75	1.90	1.94	1.85	2.11	1.77	2.25	1.70	2.38	1.65	2.50
50.00	2.86	1.20	2.43	1.55	2.21	1.80	2.06	2.00	1.95	2.17	1.86	2.32	1.79	2.45	1.74	2.57
55.00	2.99	1.23	2.54	1.59	2.31	1.84	2.16	2.05	2.04	2.22	1.95	2.38	1.88	2.51	1.82	2.64
60.00	3.11	1.26	2.65	1.62	2.41	1.89	2.25	2.10	2.13	2.27	2.04	2.43	1.96	2.57	1.90	2.70
65.00	3.23	1.28	2.75	1.66	2.50	1.93	2.34	2.14	2.21	2.32	2.12	2.48	2.04	2.63	1.98	2.76
70.00	3.34	1.31	2.85	1.69	2.59	1.96	2.42	2.18	2.29	2.37	2.20	2.53	2.12	2.68	2.05	2.82
75.00	3.45	1.33	2.94	1.72	2.68	2.00	2.50	2.22	2.37	2.41	2.27	2.58	2.19	2.73	2.12	2.87
80.00	3.55	1.35	3.03	1.75	2.76	2.03	2.58	2.26	2.45	2.45	2.34	2.63	2.26	2.78	2.19	2.92
85.00	3.65	1.37	3.12	1.78	2.84	2.07	2.65	2.30	2.52	2.49	2.41	2.67	2.32	2.82	2.25	2.97
90.00	3.75	1.39	3.20	1.80	2.91	2.10	2.73	2.33	2.59	2.53	2.48	2.71	2.39	2.87	2.31	3.01
95.00	3.84	1.41	3.28	1.83	2.99	2.13	2.79	2.36	2.65	2.57	2.54	2.75	2.45	2.91	2.37	3.05
100.00	3.93	1.43	3.36	1.85	3.06	2.15	2.86	2.40	2.72	2.60	2.60	2.78	2.51	2.95	2.43	3.10
105.00	4.01	1.45	3.43	1.88	3.13	2.18	2.93	2.43	2.78	2.64	2.66	2.82	2.57	2.98	2.49	3.13
110.00	4.10	1.47	3.51	1.90	3.20	2.21	2.99	2.46	2.84	2.67	2.72	2.85	2.63	3.02	2.54	3.17
115.00	4.18	1.48	3.58	1.92	3.26	2.23	3.05	2.48	2.90	2.70	2.78	2.89	2.68	3.06	2.60	3.21
120.00	4.26	1.50	3.65	1.94	3.33	2.26	3.11	2.51	2.96	2.73	2.84	2.92	2.74	3.09	2.65	3.25
125.00	4.34	1.52	3.72	1.96	3.39	2.28	3.17	2.54	3.01	2.76	2.89	2.95	2.79	3.12	2.70	3.28
130.00	4.41	1.53	3.78	1.98	3.45	2.30	3.23	2.56	3.07	2.79	2.94	2.98	2.84	3.16	2.75	3.32

Constants — sideslope Z = 3.00 ; bottom width , b = 6.00 ft ; Mannings n = 0.040
Enter chart with discharge , Q (cfs) and channel slope , s (ft./ ft.)
Find — depth , d (ft.) and Velocity , V (ft./sec.)

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

Z = 3.00
b = 8.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.31	.36	.26	.45	.23	.51	.21	.56	.20	.60	.19	.63	.18	.66	.17	.69
2.00	.47	.45	.39	.57	.34	.65	.31	.71	.29	.77	.28	.81	.27	.85	.26	.89
3.00	.59	.52	.49	.65	.43	.75	.40	.82	.37	.88	.35	.94	.34	.99	.33	1.03
4.00	.70	.57	.57	.72	.51	.82	.47	.91	.44	.98	.42	1.04	.40	1.09	.39	1.14
5.00	.79	.61	.65	.77	.58	.89	.53	.98	.50	1.05	.48	1.12	.46	1.18	.44	1.23
10.00	1.16	.75	.96	.96	.86	1.11	.79	1.22	.74	1.32	.71	1.40	.68	1.48	.65	1.55
15.00	1.44	.85	1.19	1.09	1.07	1.25	.99	1.38	.93	1.50	.88	1.59	.85	1.68	.82	1.76
20.00	1.67	.92	1.39	1.18	1.25	1.36	1.16	1.51	1.09	1.63	1.04	1.74	.99	1.84	.96	1.92
25.00	1.87	.98	1.57	1.26	1.41	1.46	1.30	1.61	1.23	1.74	1.17	1.86	1.12	1.96	1.08	2.06
30.00	2.05	1.03	1.72	1.33	1.55	1.53	1.44	1.70	1.35	1.84	1.29	1.96	1.24	2.07	1.19	2.17
35.00	2.22	1.08	1.86	1.38	1.68	1.60	1.56	1.78	1.47	1.92	1.40	2.05	1.34	2.17	1.30	2.27
40.00	2.37	1.12	1.99	1.44	1.80	1.66	1.67	1.84	1.57	2.00	1.50	2.13	1.44	2.25	1.39	2.36
45.00	2.51	1.15	2.12	1.48	1.91	1.72	1.77	1.91	1.67	2.07	1.60	2.20	1.53	2.33	1.48	2.44
50.00	2.65	1.19	2.23	1.53	2.01	1.77	1.87	1.96	1.77	2.13	1.69	2.27	1.62	2.40	1.57	2.52
55.00	2.77	1.22	2.34	1.57	2.11	1.82	1.97	2.02	1.86	2.19	1.77	2.33	1.70	2.47	1.64	2.59
60.00	2.89	1.24	2.44	1.60	2.21	1.86	2.05	2.06	1.94	2.24	1.85	2.39	1.78	2.53	1.72	2.65
65.00	3.01	1.27	2.54	1.64	2.30	1.90	2.14	2.11	2.02	2.29	1.93	2.44	1.86	2.58	1.79	2.71
70.00	3.11	1.30	2.63	1.67	2.38	1.94	2.22	2.15	2.10	2.34	2.00	2.49	1.93	2.64	1.86	2.77
75.00	3.22	1.32	2.72	1.70	2.47	1.98	2.30	2.19	2.17	2.38	2.08	2.54	2.00	2.69	1.93	2.82
80.00	3.32	1.34	2.81	1.73	2.55	2.01	2.37	2.23	2.24	2.42	2.14	2.59	2.06	2.74	1.99	2.87
85.00	3.42	1.36	2.89	1.76	2.62	2.04	2.44	2.27	2.31	2.46	2.21	2.63	2.13	2.78	2.06	2.92
90.00	3.51	1.39	2.98	1.79	2.70	2.08	2.51	2.31	2.38	2.50	2.27	2.67	2.19	2.83	2.12	2.97
95.00	3.60	1.40	3.05	1.81	2.77	2.11	2.58	2.34	2.44	2.54	2.34	2.71	2.25	2.87	2.17	3.01
100.00	3.69	1.42	3.13	1.84	2.84	2.13	2.65	2.37	2.51	2.57	2.40	2.75	2.31	2.91	2.23	3.05
105.00	3.77	1.44	3.20	1.86	2.91	2.16	2.71	2.40	2.57	2.61	2.45	2.79	2.36	2.95	2.29	3.10
110.00	3.85	1.46	3.28	1.89	2.97	2.19	2.77	2.43	2.63	2.64	2.51	2.82	2.42	2.99	2.34	3.13
115.00	3.93	1.48	3.34	1.91	3.04	2.21	2.83	2.46	2.68	2.67	2.57	2.86	2.47	3.02	2.39	3.17
120.00	4.01	1.49	3.41	1.93	3.10	2.24	2.89	2.49	2.74	2.70	2.62	2.89	2.52	3.06	2.44	3.21
125.00	4.09	1.51	3.48	1.95	3.16	2.26	2.95	2.52	2.79	2.73	2.67	2.92	2.57	3.09	2.49	3.24
130.00	4.16	1.52	3.54	1.97	3.22	2.29	3.01	2.54	2.85	2.76	2.73	2.95	2.62	3.12	2.54	3.28
135.00	4.24	1.54	3.61	1.99	3.28	2.31	3.06	2.57	2.90	2.79	2.78	2.98	2.67	3.15	2.59	3.31
140.00	4.31	1.55	3.67	2.01	3.34	2.33	3.11	2.59	2.95	2.82	2.83	3.01	2.72	3.19	2.63	3.34
145.00	4.38	1.57	3.73	2.03	3.39	2.35	3.17	2.62	3.00	2.84	2.87	3.04	2.77	3.22	2.68	3.38
150.00	4.45	1.58	3.79	2.04	3.45	2.37	3.22	2.64	3.05	2.87	2.92	3.07	2.81	3.24	2.72	3.41

Constants — sideslope Z = 3.00 ; bottom width , b = 8.00 ft ; Mannings n = 0.040
Enter chart with discharge , Q (cfs) and channel slope , s (ft./ ft.)
Find — depth , d (ft.) and Velocity , V (ft./sec.)

CHANNEL DESIGN TABLES - TRIANGULAR SECTION

Z = 4.00
b = 0.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.76	.43	.67	.56	.62	.65	.59	.72	.57	.78	.55	.84	.53	.89	.52	.94
2.00	.99	.51	.87	.66	.81	.77	.76	.86	.73	.93	.71	1.00	.69	1.06	.67	1.11
3.00	1.15	.56	1.01	.73	.94	.85	.89	.95	.85	1.03	.83	1.10	.80	1.17	.78	1.23
4.00	1.29	.61	1.13	.79	1.05	.92	.99	1.02	.95	1.11	.92	1.19	.89	1.26	.87	1.32
5.00	1.40	.64	1.23	.83	1.14	.97	1.08	1.08	1.03	1.17	1.00	1.26	.97	1.33	.95	1.40
10.00	1.81	.76	1.59	.99	1.48	1.15	1.40	1.28	1.34	1.39	1.30	1.49	1.26	1.58	1.23	1.66
15.00	2.11	.84	1.85	1.09	1.72	1.27	1.63	1.42	1.56	1.54	1.51	1.65	1.47	1.75	1.43	1.84
20.00	2.35	.91	2.06	1.18	1.91	1.37	1.81	1.52	1.74	1.66	1.68	1.77	1.63	1.88	1.59	1.98
25.00	2.55	.96	2.24	1.24	2.08	1.45	1.97	1.61	1.89	1.75	1.83	1.88	1.77	1.99	1.73	2.09
30.00	2.74	1.00	2.40	1.30	2.23	1.51	2.11	1.69	2.02	1.83	1.96	1.96	1.90	2.08	1.85	2.19
35.00	2.90	1.04	2.55	1.35	2.36	1.57	2.24	1.75	2.14	1.91	2.07	2.04	2.01	2.16	1.96	2.27
40.00	3.05	1.08	2.68	1.40	2.48	1.63	2.35	1.81	2.25	1.97	2.18	2.11	2.12	2.24	2.06	2.35
45.00	3.18	1.11	2.80	1.44	2.59	1.68	2.46	1.87	2.36	2.03	2.28	2.17	2.21	2.30	2.16	2.42
50.00	3.31	1.14	2.91	1.48	2.70	1.72	2.55	1.92	2.45	2.08	2.37	2.23	2.30	2.36	2.24	2.49
55.00	3.43	1.17	3.02	1.51	2.79	1.76	2.65	1.96	2.54	2.13	2.45	2.29	2.38	2.42	2.33	2.55
60.00	3.55	1.19	3.12	1.55	2.89	1.80	2.74	2.01	2.62	2.18	2.54	2.34	2.46	2.47	2.40	2.60
65.00	3.66	1.22	3.21	1.58	2.98	1.84	2.82	2.05	2.70	2.23	2.61	2.38	2.54	2.52	2.48	2.65
70.00	3.76	1.24	3.30	1.61	3.06	1.87	2.90	2.08	2.78	2.27	2.69	2.43	2.61	2.57	2.55	2.70
75.00	3.86	1.26	3.39	1.64	3.14	1.90	2.97	2.12	2.85	2.31	2.76	2.47	2.68	2.62	2.61	2.75
80.00	3.95	1.28	3.47	1.66	3.22	1.93	3.05	2.16	2.92	2.34	2.82	2.51	2.74	2.66	2.68	2.80
85.00	4.04	1.30	3.55	1.69	3.29	1.96	3.12	2.19	2.99	2.38	2.89	2.55	2.81	2.70	2.74	2.84
90.00	4.13	1.32	3.63	1.71	3.36	1.99	3.18	2.22	3.05	2.41	2.95	2.58	2.87	2.74	2.80	2.88
95.00	4.21	1.34	3.70	1.74	3.43	2.02	3.25	2.25	3.12	2.45	3.01	2.62	2.93	2.78	2.85	2.92
100.00	4.30	1.36	3.77	1.76	3.50	2.05	3.31	2.28	3.18	2.48	3.07	2.65	2.98	2.81	2.91	2.96

Constants – sideslope Z = 4.00 ; bottom width, b = 0 ft ; Mannings n = 0.040
Enter chart with discharge, Q (cfs) and channel slope, s (ft./ft.)
Find – depth, d (ft.) and Velocity, V (ft./sec.)

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

Z = 4.00
b = 2.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.56	.42	.48	.54	.43	.63	.40	.70	.38	.76	.36	.81	.35	.85	.34	.89
2.00	.78	.50	.66	.65	.60	.76	.56	.84	.53	.91	.51	.97	.49	1.03	.48	1.08
3.00	.94	.56	.80	.72	.73	.84	.68	.94	.65	1.02	.62	1.09	.60	1.15	.58	1.21
4.00	1.06	.60	.91	.78	.83	.91	.78	1.01	.74	1.09	.71	1.17	.68	1.24	.66	1.30
5.00	1.17	.64	1.01	.83	.92	.96	.86	1.07	.82	1.16	.79	1.24	.76	1.31	.74	1.38
10.00	1.58	.76	1.36	.98	1.25	1.15	1.17	1.28	1.12	1.39	1.07	1.48	1.04	1.57	1.01	1.65
15.00	1.88	.84	1.62	1.09	1.49	1.27	1.40	1.41	1.33	1.54	1.28	1.64	1.24	1.74	1.20	1.83
20.00	2.11	.91	1.83	1.17	1.68	1.37	1.58	1.52	1.51	1.65	1.45	1.77	1.40	1.87	1.36	1.97
25.00	2.32	.96	2.01	1.24	1.85	1.44	1.74	1.61	1.66	1.75	1.60	1.87	1.54	1.98	1.50	2.08
30.00	2.50	1.00	2.17	1.30	1.99	1.51	1.88	1.68	1.79	1.83	1.72	1.96	1.67	2.08	1.62	2.18
35.00	2.66	1.04	2.31	1.35	2.12	1.57	2.00	1.75	1.91	1.90	1.84	2.04	1.78	2.16	1.73	2.27
40.00	2.81	1.08	2.44	1.40	2.24	1.63	2.11	1.81	2.02	1.97	1.94	2.11	1.88	2.23	1.83	2.35
45.00	2.95	1.11	2.56	1.44	2.36	1.67	2.22	1.86	2.12	2.03	2.04	2.17	1.98	2.30	1.92	2.42
50.00	3.07	1.14	2.67	1.48	2.46	1.72	2.32	1.91	2.21	2.08	2.13	2.23	2.07	2.36	2.01	2.48
55.00	3.19	1.17	2.78	1.51	2.56	1.76	2.41	1.96	2.30	2.13	2.22	2.28	2.15	2.42	2.09	2.54
60.00	3.31	1.19	2.88	1.55	2.65	1.80	2.50	2.00	2.39	2.18	2.30	2.33	2.23	2.47	2.17	2.60
65.00	3.41	1.22	2.97	1.58	2.74	1.84	2.58	2.05	2.47	2.22	2.38	2.38	2.30	2.52	2.24	2.65
70.00	3.52	1.24	3.06	1.61	2.82	1.87	2.66	2.08	2.54	2.27	2.45	2.43	2.37	2.57	2.31	2.70
75.00	3.62	1.26	3.15	1.64	2.90	1.90	2.74	2.12	2.61	2.30	2.52	2.47	2.44	2.61	2.38	2.75
80.00	3.71	1.28	3.23	1.66	2.98	1.93	2.81	2.15	2.68	2.34	2.59	2.51	2.51	2.66	2.44	2.79
85.00	3.80	1.30	3.31	1.69	3.05	1.96	2.88	2.19	2.75	2.38	2.65	2.55	2.57	2.70	2.50	2.84
90.00	3.89	1.32	3.39	1.71	3.12	1.99	2.95	2.22	2.82	2.41	2.71	2.58	2.63	2.74	2.56	2.88
95.00	3.97	1.34	3.46	1.73	3.19	2.02	3.01	2.25	2.88	2.45	2.77	2.62	2.69	2.77	2.62	2.92
100.00	4.05	1.36	3.53	1.76	3.26	2.05	3.07	2.28	2.94	2.48	2.83	2.65	2.74	2.81	2.67	2.95

Constants — sideslope Z = 4.00 ; bottom width , b = 2.00 ft.; Mannings n = 0.040
Enter chart with discharge , Q (cfs) and channel slope , s (ft./ft.)
Find — depth , d (ft.) and Velocity , V (ft./sec.)

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

Z = 4.00
b = 4.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.44	.40	.36	.51	.33	.58	.30	.64	.28	.69	.27	.74	.26	.78	.25	.81
2.00	.63	.49	.53	.62	.47	.72	.44	.79	.41	.86	.39	.92	.38	.97	.36	1.01
3.00	.78	.54	.65	.70	.59	.81	.54	.90	.51	.97	.49	1.03	.47	1.09	.45	1.14
4.00	.90	.59	.75	.76	.68	.88	.63	.97	.60	1.05	.57	1.12	.55	1.19	.53	1.24
5.00	1.00	.63	.84	.81	.76	.93	.71	1.03	.67	1.12	.64	1.20	.61	1.27	.59	1.33
10.00	1.39	.75	1.18	.97	1.07	1.13	1.00	1.25	.95	1.36	.91	1.45	.87	1.53	.84	1.61
15.00	1.68	.83	1.43	1.08	1.30	1.25	1.22	1.39	1.15	1.51	1.10	1.62	1.06	1.71	1.03	1.80
20.00	1.91	.90	1.63	1.16	1.49	1.35	1.39	1.50	1.32	1.63	1.27	1.75	1.22	1.85	1.18	1.94
25.00	2.11	.95	1.81	1.23	1.65	1.43	1.54	1.59	1.47	1.73	1.41	1.85	1.36	1.96	1.31	2.06
30.00	2.29	1.00	1.96	1.29	1.79	1.50	1.68	1.67	1.60	1.81	1.53	1.94	1.48	2.05	1.43	2.16
35.00	2.45	1.04	2.10	1.34	1.92	1.56	1.80	1.74	1.71	1.89	1.64	2.02	1.58	2.14	1.54	2.25
40.00	2.59	1.07	2.23	1.39	2.04	1.62	1.91	1.80	1.82	1.95	1.74	2.09	1.68	2.21	1.63	2.33
45.00	2.73	1.11	2.35	1.43	2.15	1.67	2.01	1.85	1.92	2.01	1.84	2.16	1.78	2.28	1.72	2.40
50.00	2.86	1.14	2.46	1.47	2.25	1.71	2.11	1.90	2.01	2.07	1.93	2.21	1.86	2.34	1.81	2.46
55.00	2.98	1.16	2.56	1.51	2.35	1.75	2.20	1.95	2.10	2.12	2.01	2.27	1.95	2.40	1.89	2.52
60.00	3.09	1.19	2.66	1.54	2.44	1.79	2.29	2.00	2.18	2.17	2.09	2.32	2.02	2.46	1.96	2.58
65.00	3.19	1.21	2.75	1.57	2.52	1.83	2.37	2.04	2.26	2.21	2.17	2.37	2.10	2.51	2.03	2.64
70.00	3.30	1.24	2.84	1.60	2.61	1.86	2.45	2.08	2.33	2.25	2.24	2.41	2.17	2.56	2.10	2.69
75.00	3.39	1.26	2.93	1.63	2.68	1.90	2.52	2.11	2.40	2.29	2.31	2.46	2.23	2.60	2.17	2.73
80.00	3.49	1.28	3.01	1.66	2.76	1.93	2.59	2.15	2.47	2.33	2.38	2.50	2.30	2.64	2.23	2.78
85.00	3.58	1.30	3.09	1.68	2.83	1.96	2.66	2.18	2.54	2.37	2.44	2.54	2.36	2.69	2.29	2.82
90.00	3.66	1.32	3.17	1.71	2.90	1.99	2.73	2.21	2.60	2.40	2.50	2.57	2.42	2.72	2.35	2.86
95.00	3.75	1.34	3.24	1.73	2.97	2.01	2.79	2.24	2.66	2.44	2.56	2.61	2.48	2.76	2.40	2.90
100.00	3.83	1.35	3.31	1.75	3.04	2.04	2.86	2.27	2.72	2.47	2.62	2.64	2.53	2.80	2.46	2.94

Constants — sideslope Z = 4.00 ; bottom width , b = 4.00 ft ; Mannings n = 0.040
Enter chart with discharge , Q (cfs) and channel slope , s (ft / ft)
Find — depth , d (ft.) and Velocity , V (ft./ sec.)

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

Z = 4.00
b = 6.00
n = 0.040

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.36	.37	.30	.47	.27	.54	.24	.59	.23	.64	.22	.68	.21	.71	.20	.74
2.00	.53	.46	.44	.59	.39	.67	.36	.74	.34	.80	.32	.85	.31	.90	.30	.94
3.00	.66	.52	.55	.67	.49	.77	.45	.85	.43	.91	.41	.97	.39	1.03	.37	1.07
4.00	.77	.57	.64	.73	.58	.84	.53	.93	.50	1.00	.48	1.07	.46	1.12	.44	1.18
5.00	.87	.61	.72	.78	.65	.90	.60	.99	.57	1.07	.54	1.14	.52	1.20	.50	1.26
10.00	1.24	.74	1.04	.95	.94	1.10	.87	1.22	.82	1.32	.78	1.40	.75	1.48	.72	1.55
15.00	1.51	.82	1.28	1.06	1.15	1.23	1.07	1.36	1.01	1.48	.97	1.58	.93	1.67	.90	1.75
20.00	1.74	.89	1.47	1.15	1.33	1.33	1.24	1.48	1.17	1.60	1.12	1.71	1.08	1.81	1.04	1.90
25.00	1.93	.94	1.64	1.22	1.49	1.41	1.38	1.57	1.31	1.70	1.25	1.82	1.20	1.92	1.16	2.02
30.00	2.11	.99	1.79	1.28	1.62	1.48	1.51	1.65	1.43	1.79	1.37	1.91	1.32	2.02	1.28	2.12
35.00	2.26	1.03	1.92	1.33	1.75	1.54	1.63	1.72	1.54	1.86	1.48	1.99	1.42	2.11	1.38	2.21
40.00	2.40	1.07	2.05	1.38	1.86	1.60	1.74	1.78	1.65	1.93	1.58	2.06	1.52	2.18	1.47	2.29
45.00	2.54	1.10	2.16	1.42	1.97	1.65	1.84	1.83	1.74	1.99	1.67	2.13	1.61	2.25	1.56	2.37
50.00	2.66	1.13	2.27	1.46	2.07	1.70	1.93	1.89	1.83	2.05	1.76	2.19	1.69	2.32	1.64	2.43
55.00	2.78	1.16	2.37	1.50	2.16	1.74	2.02	1.93	1.92	2.10	1.84	2.25	1.77	2.38	1.72	2.50
60.00	2.89	1.18	2.47	1.53	2.25	1.78	2.11	1.98	2.00	2.15	1.91	2.30	1.85	2.43	1.79	2.55
65.00	2.99	1.21	2.56	1.56	2.34	1.82	2.18	2.02	2.07	2.19	1.99	2.35	1.92	2.48	1.86	2.61
70.00	3.10	1.23	2.65	1.59	2.42	1.85	2.26	2.06	2.15	2.24	2.06	2.39	1.98	2.53	1.92	2.66
75.00	3.19	1.25	2.73	1.62	2.49	1.88	2.33	2.10	2.22	2.28	2.13	2.44	2.05	2.58	1.99	2.71
80.00	3.28	1.27	2.81	1.65	2.57	1.92	2.40	2.13	2.28	2.32	2.19	2.48	2.11	2.62	2.05	2.76
85.00	3.37	1.29	2.89	1.67	2.64	1.95	2.47	2.17	2.35	2.35	2.25	2.52	2.17	2.66	2.11	2.80
90.00	3.46	1.31	2.97	1.70	2.71	1.98	2.54	2.20	2.41	2.39	2.31	2.55	2.23	2.70	2.16	2.84
95.00	3.54	1.33	3.04	1.72	2.78	2.00	2.60	2.23	2.47	2.42	2.37	2.59	2.29	2.74	2.22	2.88
100.00	3.62	1.35	3.11	1.75	2.84	2.03	2.66	2.26	2.53	2.45	2.43	2.63	2.34	2.78	2.27	2.92
105.00	3.70	1.37	3.18	1.77	2.90	2.06	2.72	2.29	2.59	2.48	2.48	2.66	2.40	2.81	2.32	2.96
110.00	3.78	1.38	3.24	1.79	2.96	2.08	2.78	2.31	2.64	2.51	2.53	2.69	2.45	2.85	2.37	2.99
115.00	3.85	1.40	3.31	1.81	3.02	2.10	2.83	2.34	2.70	2.54	2.59	2.72	2.50	2.88	2.42	3.03
120.00	3.92	1.41	3.37	1.83	3.08	2.13	2.89	2.37	2.75	2.57	2.64	2.75	2.55	2.91	2.47	3.06
125.00	3.99	1.43	3.43	1.85	3.14	2.15	2.94	2.39	2.80	2.60	2.69	2.78	2.59	2.94	2.52	3.09
130.00	4.06	1.44	3.49	1.87	3.19	2.17	2.99	2.42	2.85	2.62	2.73	2.81	2.64	2.97	2.56	3.13

Constants — sideslope Z = 4.00 ; bottom width , b = 6.00 ft ; Mannings n = 0.040
Enter chart with discharge , Q (cfs) and channel slope , s (ft./ ft.)
Find — depth , d (ft.) and Velocity , V (ft./sec.)

Z = 4.00
b = 8.00
n = 0.040

CHANNEL DESIGN TABLES - TRAPEZOIDAL SECTION

	s = .0005		s = .0010		s = .0015		s = .0020		s = .0025		s = .0030		s = .0035		s = .0040	
Q	d	V	d	V	d	V	d	V	d	V	d	V	d	V	d	V
1.00	.31	.35	.25	.44	.23	.50	.21	.55	.20	.59	.19	.62	.18	.65	.17	.68
2.00	.46	.44	.38	.56	.34	.63	.31	.70	.29	.75	.28	.80	.26	.84	.25	.87
3.00	.58	.50	.48	.63	.43	.73	.39	.80	.37	.86	.35	.92	.33	.96	.32	1.01
4.00	.68	.55	.56	.70	.50	.80	.46	.88	.43	.95	.41	1.01	.39	1.06	.38	1.11
5.00	.77	.59	.64	.75	.57	.86	.52	.95	.49	1.02	.47	1.09	.45	1.14	.43	1.19
10.00	1.12	.72	.93	.92	.83	1.06	.77	1.17	.72	1.27	.69	1.35	.66	1.43	.64	1.49
15.00	1.38	.81	1.15	1.04	1.03	1.20	.96	1.33	.90	1.43	.86	1.53	.82	1.61	.80	1.69
20.00	1.59	.88	1.33	1.12	1.20	1.30	1.12	1.44	1.05	1.56	1.00	1.66	.96	1.76	.93	1.84
25.00	1.78	.93	1.50	1.20	1.35	1.38	1.25	1.54	1.18	1.66	1.13	1.78	1.08	1.88	1.05	1.97
30.00	1.95	.98	1.64	1.26	1.48	1.46	1.38	1.62	1.30	1.75	1.24	1.87	1.19	1.98	1.15	2.07
35.00	2.10	1.02	1.77	1.31	1.60	1.52	1.49	1.69	1.41	1.83	1.34	1.95	1.29	2.06	1.25	2.17
40.00	2.24	1.06	1.89	1.36	1.71	1.58	1.59	1.75	1.50	1.90	1.44	2.03	1.38	2.14	1.33	2.25
45.00	2.37	1.09	2.00	1.40	1.81	1.63	1.69	1.81	1.60	1.96	1.53	2.10	1.47	2.21	1.42	2.32
50.00	2.49	1.12	2.11	1.44	1.91	1.68	1.78	1.86	1.68	2.02	1.61	2.16	1.55	2.28	1.50	2.39
55.00	2.60	1.15	2.21	1.48	2.00	1.72	1.86	1.91	1.76	2.07	1.69	2.21	1.62	2.34	1.57	2.46
60.00	2.71	1.18	2.30	1.52	2.09	1.76	1.95	1.96	1.84	2.12	1.76	2.27	1.69	2.40	1.64	2.52
65.00	2.81	1.20	2.39	1.55	2.17	1.80	2.02	2.00	1.92	2.17	1.83	2.32	1.76	2.45	1.71	2.57
70.00	2.91	1.22	2.48	1.58	2.25	1.83	2.10	2.04	1.99	2.21	1.90	2.36	1.83	2.50	1.77	2.62
75.00	3.01	1.25	2.56	1.61	2.32	1.87	2.17	2.08	2.05	2.25	1.97	2.41	1.89	2.55	1.83	2.67
80.00	3.10	1.27	2.64	1.64	2.40	1.90	2.24	2.11	2.12	2.29	2.03	2.45	1.95	2.59	1.89	2.72
85.00	3.19	1.29	2.71	1.66	2.47	1.93	2.30	2.15	2.18	2.33	2.09	2.49	2.01	2.63	1.95	2.77
90.00	3.27	1.31	2.79	1.69	2.53	1.96	2.37	2.18	2.24	2.37	2.15	2.53	2.07	2.68	2.00	2.81
95.00	3.35	1.32	2.86	1.71	2.60	1.99	2.43	2.21	2.30	2.40	2.20	2.57	2.12	2.71	2.06	2.85
100.00	3.43	1.34	2.93	1.73	2.66	2.02	2.49	2.24	2.36	2.43	2.26	2.60	2.18	2.75	2.11	2.89
105.00	3.51	1.36	2.99	1.76	2.72	2.04	2.55	2.27	2.42	2.46	2.31	2.63	2.23	2.79	2.16	2.93
110.00	3.58	1.38	3.06	1.78	2.78	2.07	2.60	2.30	2.47	2.49	2.36	2.67	2.28	2.82	2.21	2.96
115.00	3.66	1.39	3.12	1.80	2.84	2.09	2.66	2.32	2.52	2.52	2.41	2.70	2.33	2.86	2.25	3.00
120.00	3.73	1.41	3.18	1.82	2.90	2.11	2.71	2.35	2.57	2.55	2.46	2.73	2.38	2.89	2.30	3.03
125.00	3.80	1.42	3.24	1.84	2.95	2.14	2.76	2.38	2.62	2.58	2.51	2.76	2.42	2.92	2.35	3.07
130.00	3.86	1.44	3.30	1.86	3.01	2.16	2.81	2.40	2.67	2.61	2.56	2.79	2.47	2.95	2.39	3.10
135.00	3.93	1.45	3.36	1.88	3.06	2.18	2.86	2.42	2.72	2.63	2.61	2.82	2.51	2.98	2.43	3.13
140.00	3.99	1.46	3.42	1.89	3.11	2.20	2.91	2.45	2.77	2.66	2.65	2.84	2.56	3.01	2.48	3.16
145.00	4.06	1.48	3.47	1.91	3.16	2.22	2.96	2.47	2.81	2.68	2.69	2.87	2.60	3.04	2.52	3.19
150.00	4.12	1.49	3.52	1.93	3.21	2.24	3.01	2.49	2.86	2.71	2.74	2.89	2.64	3.06	2.56	3.22

Constants — sideslope Z = 4.00 ; bottom width , b = 8.00 ft ; Mannings n = 0.040
Enter chart with discharge , Q (cfs) and channel slope , s (ft./ ft.)
Find — depth , d (ft.) and Velocity , V (ft./ sec.)

APPENDIX D

DRAINAGE COEFFICIENTS

1. Where drainage is uniform over an area through a systematic pattern of drains, and surface water is removed by field ditches or watercourses, the coefficient should be as shown in Table D-1. Figure only the area to be drained as the drainage area.

2. Where it is necessary to admit surface water through surface inlets to the drain, an adjustment in the required capacity of the drain must be made. Runoff from an area served by a surface water inlet takes place soon after the rainfall and enters the drain ahead of the groundwater. In short lines or small systems where only 1 or 2 inlets are installed, the size of the drain may not need to be increased. As systems become larger or the inlets more numerous, an adjustment to the drainage coefficient should be made. The timing of the surface waterflow in relation to the entrance of groundwater into the drain should be the basis for increasing the coefficient over those shown in Table D-1.

3. A higher coefficient than those given in Table D-1 may be necessary in some instances to hold crop damage to a minimum.

Table D-1 Drainage coefficients

Soil	Inches to be removed in 24 hours	
	Field Crops inches	Truck Crops inches
Mineral	3/8 - 1/2	1/2 - 3/4
Organic	1/2 - 3/4	3/4 - 1-1/2

From Chapter 14; Engineering Field Manual for Conservation Practices; USDA, SCS.

APPENDIX D

SUBSURFACE DRAIN GRADES AND VELOCITIES

Subsurface drains are placed at rather uniform depths; therefore, the topography of the land may dictate the range of grades available. There is often an opportunity, however, to orient the drains within the field in order to obtain a desirable grade. The selected grades should, if possible, be sufficient to result in a nonsilting velocity which experience has shown is about 1.4 feet per second, but less than that which will cause turbulence and undermining of the drain. Where siltation is a hazard (refer to Table D-3, Appendix D), and the velocity is less than 1.4 feet per second, siltation may be prevented by use of filters and silt traps.

Where siltation is not a hazard, the recommended minimum grades are as follows:

	Percent
4" drain	.10
5" drain	.07
6" drain	.05

On sites where topographic conditions require the use of drains on steep grades which will result in velocities greater than shown in Table D-2, special measures should be used to protect the line.

Table D-2 Maximum allowable velocities in drains

Soil Texture	Velocity-ft./sec.
Sand and sandy loam	3.5
Silt and silt loam	5.0
Silty clay loam	6.0
Clay and clay loam	7.0
Coarse sand or gravel	9.0

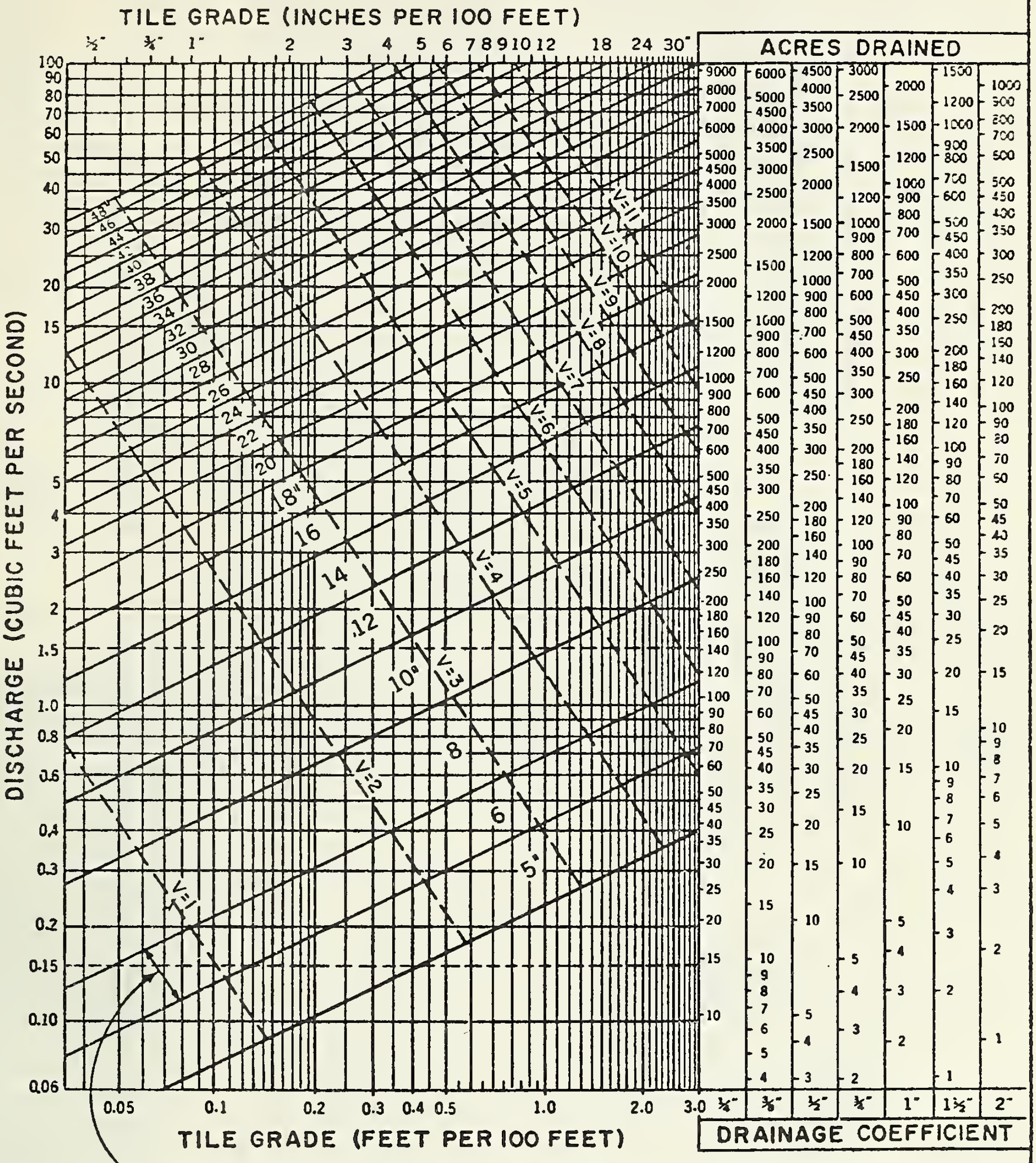
The protective measures may include one or more of the following:

1. Use only drains that are uniform in size and shape and with smooth ends.
2. Lay the drains so as to secure a tight fit with the inside diameter of one section matching that of the adjoining sections.
3. Wrap open joints with tar impregnated paper, burlap, or special filter material such as plastic or fiber-glass fabrics.
4. Select the least erodible soil available for blinding.
5. Use long sections of perforated pipe or tubing, (Bituminized fiber, plastic, asbestos cement, etc.).

From Chapter 4, <u>National Engineering Handbook, Section 16, Drainage</u>.

TILE DRAINAGE CHART

ACRES DRAINED BY VARIOUS SIZES OF TILE

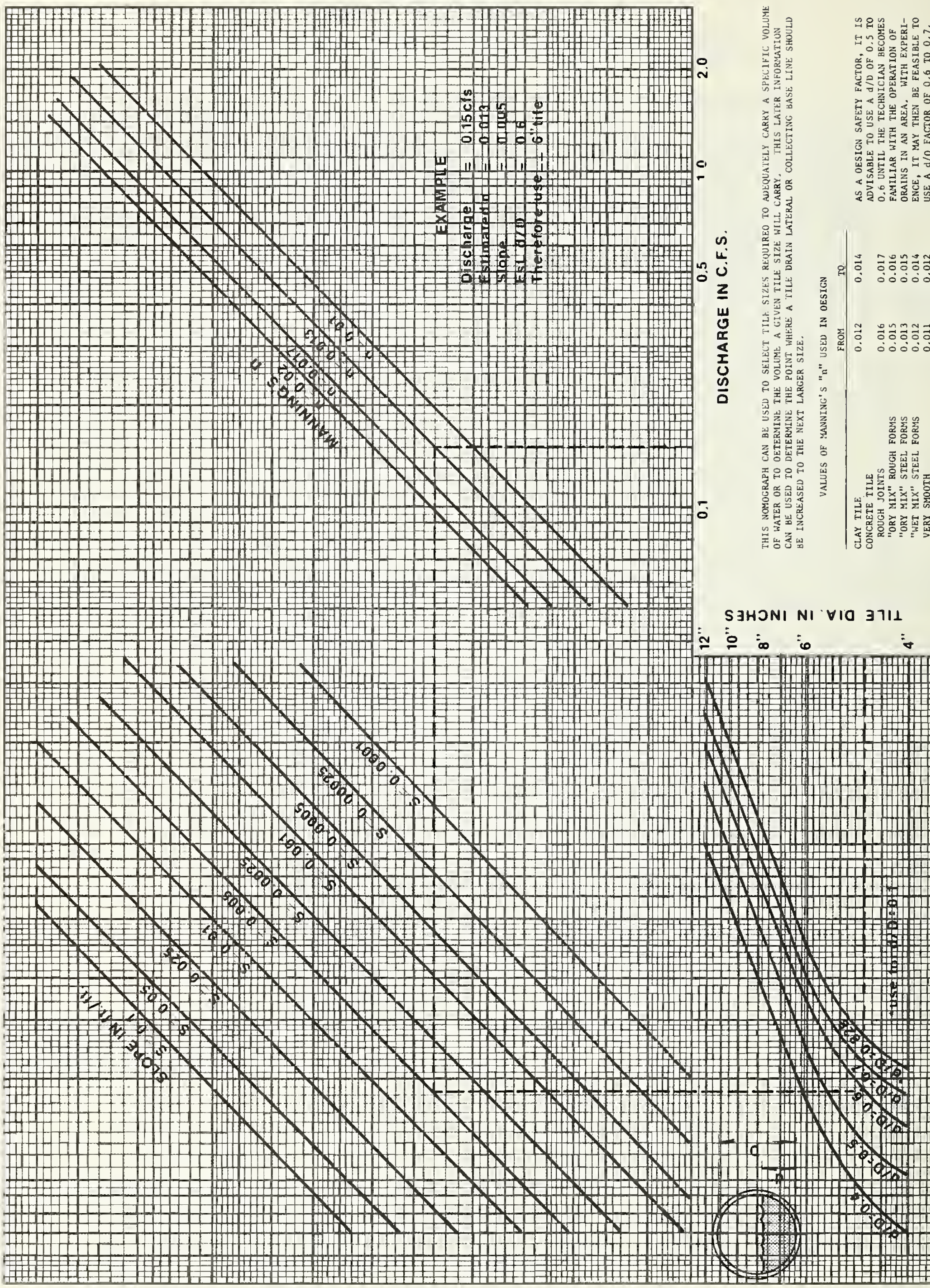


Space between lines is the range of tile capacity for the size shown between lines

V = Velocity (feet per second)

REFERENCE		STANDARD DWG. NO.
Tile drainage chart based on Yarnell formula.	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DRAINAGE SECTION	ES- 714 SHEET____OF ____ REVISED 2-2-59

Figure D-1 Chart for determining required size of clay or concrete drain tile



THIS NOMOGRAPH CAN BE USED TO SELECT TILE SIZES REQUIRED TO ADEQUATELY CARRY A SPECIFIC VOLUME OF WATER OR TO OETERMINE THE VOLUME A GIVEN TILE SIZE WILL CARRY. THIS LATER INFORMATION CAN BE USED TO DETERMINE THE POINT WHERE A TILE DRAIN LATERAL OR COLLECTING BASE LINE SHOULD BE INCREASED TO THE NEXT LARGER SIZE.

VALUES OF MANNING'S "n" USED IN OESIGN

	FROM	TO
CLAY TILE	0.012	0.014
CONCRETE TILE		
ROUGH JOINTS	0.016	0.017
"ORY MIX" ROUGH FORMS	0.015	0.016
"ORY MIX" STEEL FORMS	0.013	0.015
"WET MIX" STEEL FORMS	0.012	0.014
VERY SMOOTH	0.011	0.012
CORRUGATED TUBING	0.016	0.018

AS A OESIGN SAFETY FACTOR, IT IS ADVISABLE TO USE A d/D OF 0.5 TO 0.6 UNTIL THE TECHNICIAN BECOMES FAMILIAR WITH THE OPERATION OF ORAINS IN AN AREA. WITH EXPERIENCE, IT MAY THEN BE FEASIBLE TO USE A d/O FACTOR OF 0.6 TO 0.7.

Figure D-2 Tile Discharge Design Chart

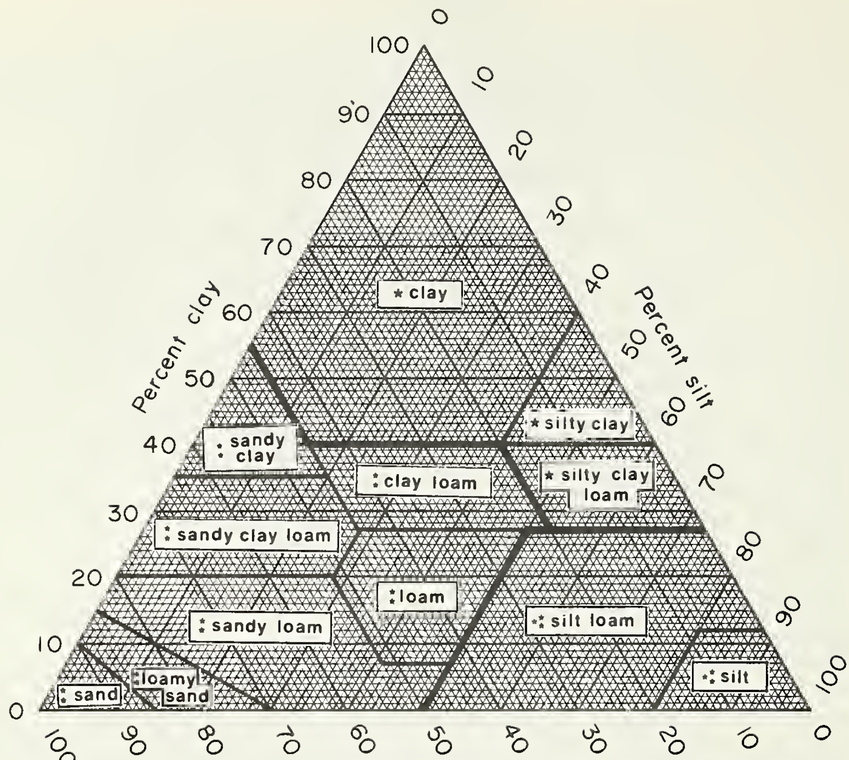
APPENDIX D

A CLASSIFICATION TO DETERMINE THE NEED FOR DRAIN FILTERS OR ENVELOPES, AND MINIMUM VELOCITIES IN DRAINS

Unified Soil Classification	Soil Description	Filter Recommendation	Envelope Recommendation	Recommendations for Minimum Drain Velocity
SP (fine) SM (fine) ML MH	Poorly graded sands, gravelly sands. Silty sands, poorly graded sand-silt mixture. Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity. Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Filter needed	Not needed where sand and gravel filter is used but may be needed with flexible drain tubing and other type filters.	None
GP SC GM SM (coarse)	Poorly graded gravels, gravel-sand mixtures, little or no fines. Clayey sands, poorly graded sand-clay mixtures. Silty gravels, poorly graded gravel-sand silt mixtures. Silty sands, poorly graded sand-silt mixtures.	Subject to local on-site determination.	Not needed where sand and gravel filter is used but may be needed with flexible drain tubing and other type filters.	With filter - none. Without filter - 1.40 feet/second.
GC CL SP,GP(coarse) GW SW CH OL OH Pt	Clayey gravels, poorly graded gravel-sand-clay mixtures Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. Same as SP & GP above. Well graded gravels, gravel-sand mixtures, little or no fines. Well graded sands, gravelly sands, little or no fines. Inorganic, fat clays Organic silts and organic silt-clays of low plasticity. Organic clays of medium to high plasticity. Peat	None	Optional. May be needed with flexible drain tubing.	None - for soils with little or no fines. 1.40 feet/second for soils with appreciable fines.

REFERENCE: This chart was developed by William F. Long and Ralph Brownscombe.	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DRAINAGE SECTION	STANDARD DWG. NO ES - 722 SHEET 1 OF 1 DATE 8-3-70

Table D-3 The Need for Drain Filters or Envelopes



*Filters are not needed.

**Sand and Gravel filter or spun bonded nylon fabric (Drainguard or equal) to restrict movement of particles that would deposit in drain.

*:Sand and Gravel filter to restrict movement of particles that would deposit in drain.

Guide For Use Of Filter Material To Protect Corrugated Drainage Tubing

Comparison of Particle Size Scales

USDA	Gravel	Sand					Silt	Clay
		Very Coarse	Coarse	Medium	Fine	Very Fine		

UNIFIED	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

AASHO	Gravel or Rock			Sand		Silt or Clay	
	Coarse	Medium	Fine	Coarse	Fine	Silt	Clay

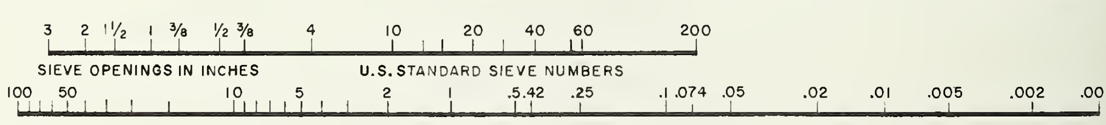


Figure D-3

APPENDIX D

TYPES OF BEDDING, FILTER, ENVELOPE, AND BACKFILL MATERIALS
for use with
Clay Tile, Concrete Tile or Pipe, or Polyethylene Drainage Tubing

See sketched for recommended placement positions

I. Sand and Gravel, Crushed Stone

a. Filter:
   Properly graded for base soil material and tile spacing. See Form OR-23 for design criteria.
b. Envelope:
   Can be graded sand and gravel or crushed stone, or sized gravel or crushed stone.

See Standard Drain Code 606 for specifications for filter and envelope materials.

II. Organic Materials

a. Envelope, Filter, or Backfill:
   Straw, grass residue, sawdust, wood chips, shavings, bark chips or shreddings.

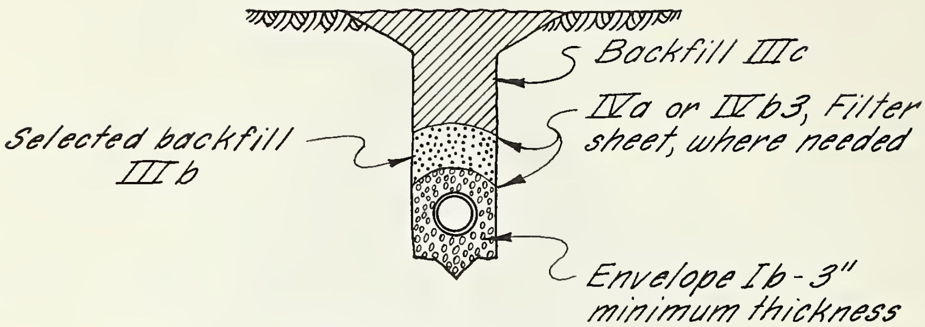
III. Soil Materials

a. Envelope:
   Selected porous soils, generally the topsoil. For blinding, it can be spaded from edge of trench as noted on sketches.
b. Selected Backfill:
   Same as III a.
c. Common Backfill:
   Trench run materials.

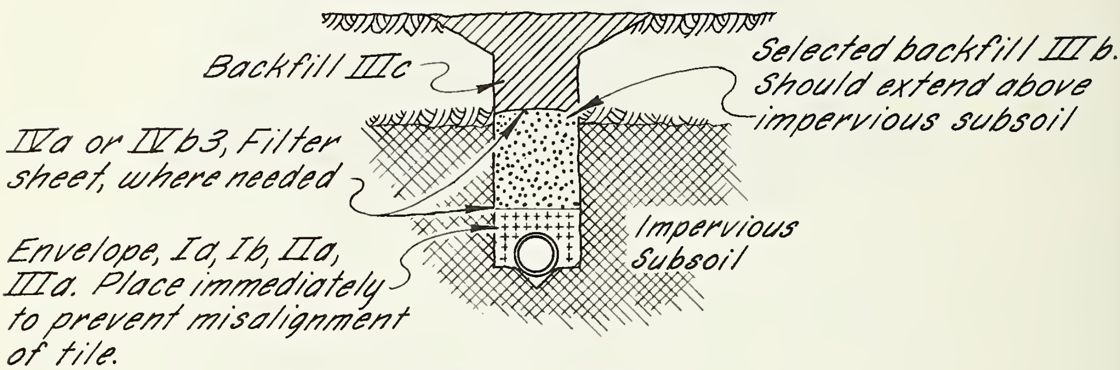
IV. Manufactured Materials

a. Filter:
   1. Spun bonded nylon fabric sock.
   2. Fiber-glass filter (Tile Guard) with a width equal to at least 1/2 the tile or tubing circumference.
b. Joint Covering - Barrier:
   Joint Coverings are needed only where joints are open wide enough to permit movement of soil into the drain.
   1. Broken pieces of pipe or tile
   2. Asphalt roofing paper or roofing shingles
   3. Heavy plastic sheeting (+ 20 mils)

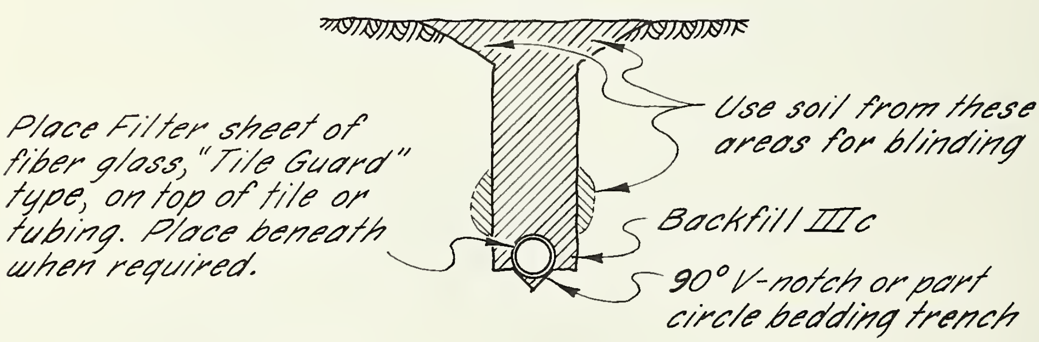
Note: Blinding of tile or tubing to prevent movement should be done immediately after or concurrently with the laying operations. Envelope, filter, or backfill materials, as noted in sketches, can be used to blind drains.



SKETCH NO. 1



SKETCH NO. 2



SKETCH NO. 3

Figure D-4 Typical backfills, envelopes and filters

APPENDIX E

USEFUL SCS FORMS

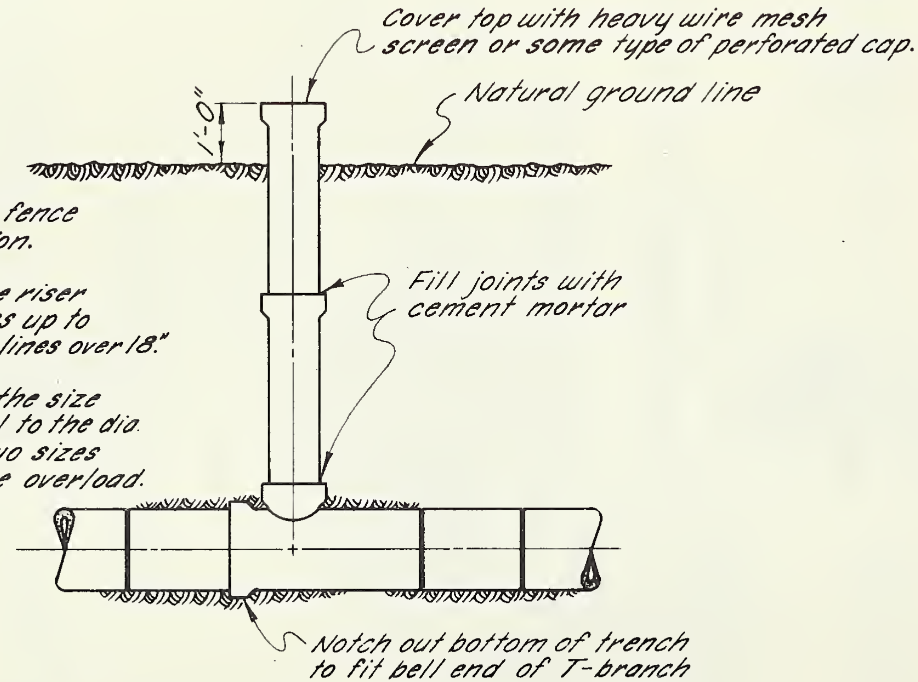
Form No.	Title
OR-ENG-6	Drain Tile and Pipeline Data Sheet
OR-13	Field Hydraulic Conductivity Test-Auger Hole Method
OR-14	Piezometer Log
OR-15	Field Hydraulic Conductivity Test-Piezometer Method
OR-16	Well or Piezometer Records
SCS-130	Material Testing Report-Drain Materials

Notes:

1. Locate riser in a permanent fence line or in a protected location.

2. When used as a breather the riser should be 4" dia. for tile lines up to & including 15" tile and 6" on lines over 18".

3. When used as a relief well the size of the riser should be equal to the dia. of the tile line or one or two sizes smaller depending upon the overload.



STANDPIPE, BREATHER OR RELIEF WELL DETAIL

Scale = None

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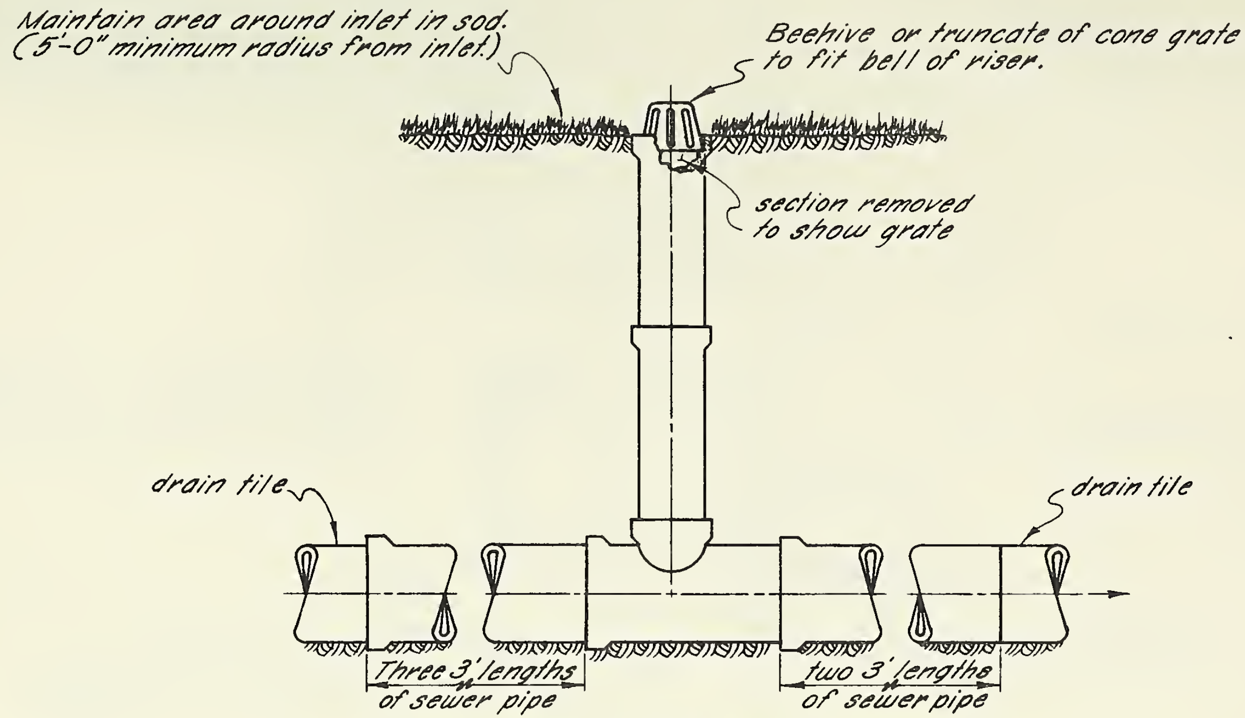

SURFACE WATER INLET DETAIL

Construction Notes:
1. Notch out bottom of tile trench to fit bell end of each sewer pipe.
2. Fill all sewer pipe joints with cement mortar and encase each joint in concrete.
3. Tamp back fill around riser after concrete has hardened.
4. Use standard strength vitrified clay sewer pipe conforming to A.S.T.M. specification C-13.

scale = none

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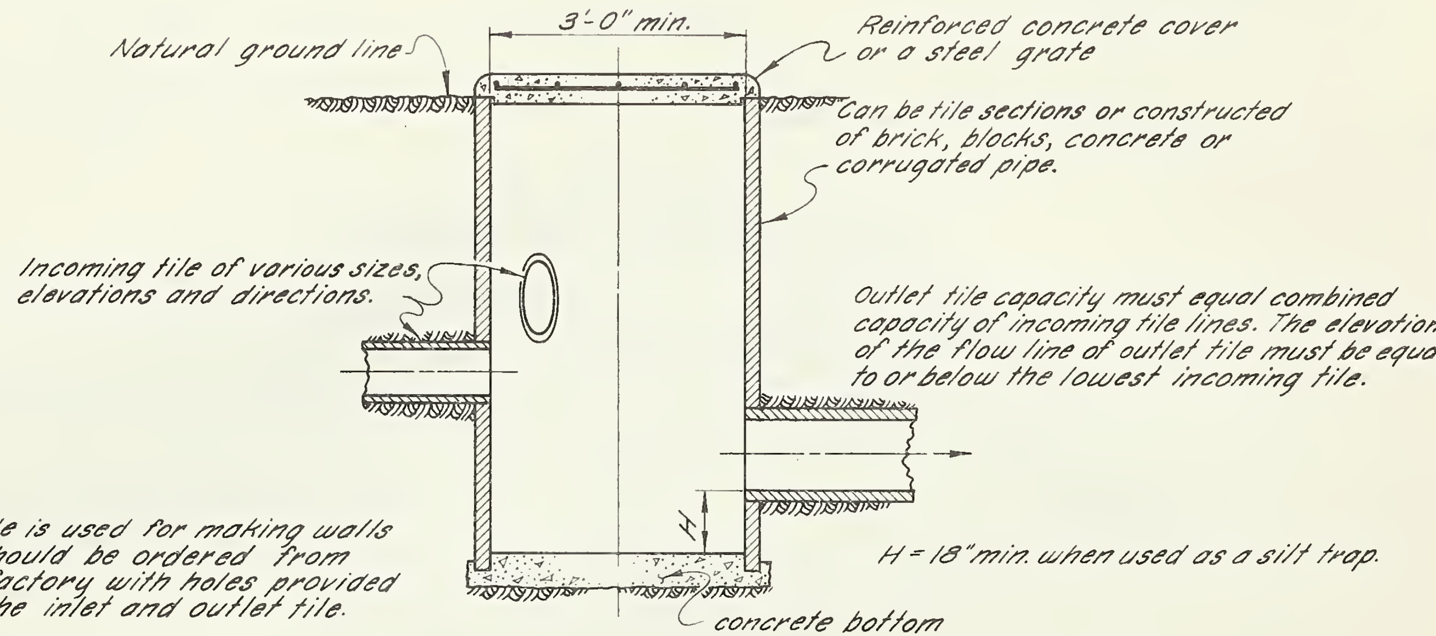

Note: If tile is used for making walls it should be ordered from the factory with holes provided for the inlet and outlet tile.

JUNCTION BOX FOR TILE LINES DETAIL

scale = none

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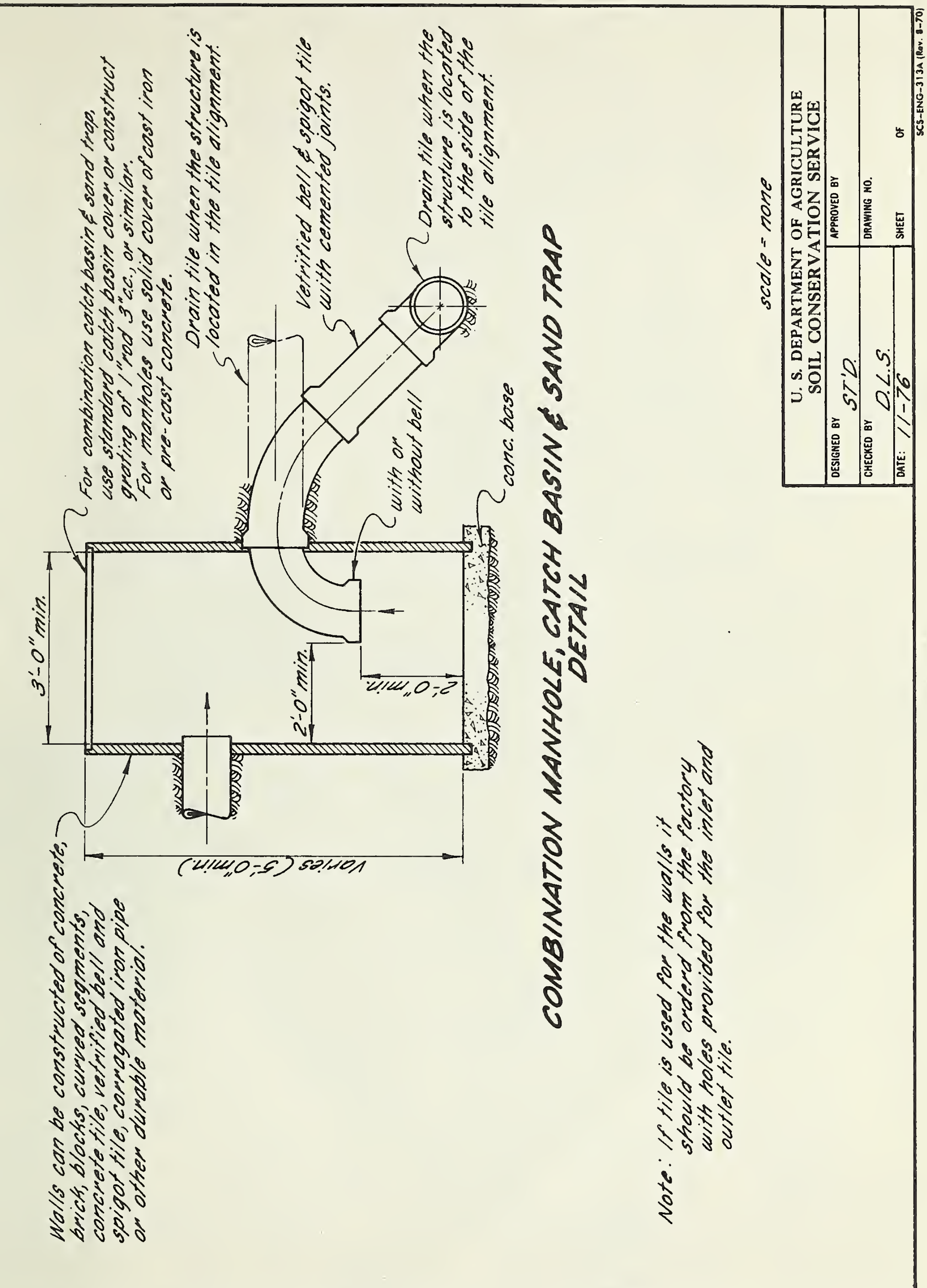
COMBINATION MANHOLE, CATCH BASIN & SAND TRAP
DETAIL
Walls can be constructed of concrete, brick, blocks, curved segments, concrete tile, vetrified bell and spigot tile, corrugated iron pipe or other durable material.
For combination catch basin & sand trap, use standard catch basin cover or construct grating of 1" rod 3" cc., or similar. For manholes use solid cover of cast iron or pre-cast concrete.
Drain tile when the structure is located in the tile alignment.
Vetrified bell & spigot tile with cemented joints.
Drain tile when the structure is located to the side of the tile alignment.
with or without bell
conc. base
3'-0" min.
2'-0" min.
2'-0" min.
Varies (5'-0" min.)
Note: If tile is used for the walls it should be orderd from the factory with holes provided for the inlet and outlet tile.
scale - none
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